UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northwest Fisheries Science Center
2725 Montlake Boulevard East
SEATTLE, WASHINGTON 98112-2097

July 26, 2005

MEMORANDUM FOR: D. Robert Lohn
Northwest Regional Administrator

Usha Varanasi

FROM: Usha Varanasi
Science and Research Director
Northwest Fisheries Science Center

SUBJECT: Summary of Scientific Conclusions of the Review of the Status of Puget Sound steelhead (*Oncorhynchus mykiss*)

The Northwest Fisheries Science Center's Biological Review Team (BRT) for Puget Sound steelhead met at the Center from July 21-23, 2005. The BRT discussed information on the Puget Sound steelhead ESU received from state and tribal co-managers regarding ESU delineation, artificial propagation, the relationship between resident and anadromous fish, and factors affecting extinction risk. Much of this information was provided electronically on July 6th and at a technical workshop at the Center on July 20th.

Attached is the BRT's report. The report summarizes the BRT's scientific conclusions regarding the ESU and its extinction risk. The report addresses specifically the following issues raised by the Region in an April 2005 memo to the Center:

1. If the Puget Sound steelhead ESU merits redelineation or refinement, describe the composition and geographic range of the redefined ESU. In your review, … please describe the relationship of resident populations to the defined ESU….In addition, please identify those hatchery programs propagating *O. mykiss* in the Puget Sound area that are part of the defined ESU.

2. Please describe the level of extinction risk of the Puget Sound *O. mykiss* ESU throughout all or a significant portion of its range. Please describe the ESU's status with reference to its abundance, productivity, spatial structure, and diversity. In assessing the level of extinction risk faced by the ESU, please include in your consideration, to the extent possible, the contribution of within-ESU resident populations and hatchery programs to the viability of the ESU.

The BRT's report describes threats to the viability of Puget Sound ESU and discusses associated uncertainties in evaluating them. In preparing its report, the BRT relied heavily on valuable information and analyses provided by Washington state and tribal co-managers and by Washington Trout.

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Status Review Update for Puget Sound Steelhead

26 July 2005

2005 Puget Sound Steelhead Biological Review Team
National Marine Fisheries Service
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The Biological Review Team (BRT) for the status review for Puget Sound steelhead included, from the NMFS Northwest Fisheries Science Center, Seattle, Washington: Dr. Barry Berejikian, Dr. Michael Ford, Dr. Jeffrey Hard, Dr. Robert Kope, Dr. James Myers, George Pess, William Waknitz, Dr. Robin Waples, and Dr. Gary Winans; from NMFS Southwest Fisheries Science Center, Santa Cruz, California: Dr. Peter Adams; from the U.S. Fish and Wildlife Service, Abernathy, Washington: Dr. Donald Campton; from the U.S. Geological Survey Biological Resources Division, Seattle, Washington: Dr. Reginald Reisenbichler; and from the U.S. Forest Service Pacific Northwest Research Station, Olympia, Washington: Dr. Peter Bisson. Dr. Paul McElhany, Northwest Fisheries Science Center, contributed to this report.

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Introduction

The U.S. Endangered Species Act (ESA) is intended to conserve threatened and endangered species in their native habitats. The ESA defines a "species" to include "any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." According to National Marine Fisheries Service (NMFS) policy (56 FR 58612), a salmon population or group of populations is considered a "distinct populations segment" and hence a "species" under the ESA if it represents an evolutionarily significant unit (ESU) of the biological species. An ESU is defined as a population that 1) is substantially reproductively isolated from conspecific populations and 2) represents an important component of the evolutionary legacy of the species.

The term "evolutionary legacy" is used in the sense of "inheritance"—that is, something received from the past and carried forward into the future. Specifically, the evolutionary legacy of a species is the genetic variability that is a product of past evolutionary events and that represents the reservoir upon which future evolutionary potential depends. Conservation of these genetic resources should help to ensure that the dynamic process of evolution will not be unduly constrained in the future.

The NMFS policy identifies a number of types of evidence that should be considered in the species determination. For each of the two criteria (reproductive isolation and evolutionary legacy), the NMFS policy advocates a holistic approach that considers all types of available information as well as their strengths and limitations. Isolation does not have to be absolute, but it must be strong enough to permit evolutionarily important differences to accrue in different population units. Important types of information to consider include natural rates of straying and recolonization, evaluations of the efficacy of natural barriers, and measurements of genetic differences between populations. Data from protein electrophoresis or DNA analyses can be particularly useful for this criterion because they reflect levels of gene flow that have occurred over evolutionary time scales.

The key question with respect to the second criterion is, if the population became extinct, would this represent a significant loss to the ecological or genetic diversity of the species? Again, a variety of types of information should be considered. Phenotypic and life-history traits such as size, fecundity, migration patterns, and age and time of spawning may reflect local adaptations of evolutionary importance, but interpretation of these traits is complicated by their sensitivity to environmental conditions. Data from protein electrophoresis or DNA analyses provide valuable insight into the process of genetic differentiation among populations but little direct information regarding the extent of adaptive genetic differences. Habitat differences suggest the possibility for local adaptations but do not prove that such adaptations exist.

The identification of an ESU is a prerequisite to the evaluation of the risk of extinction for that ESU. The ESA (section 3) defines the term "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range." The term "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." NMFS considers a variety of information in evaluating the level of risk faced by an ESU. Important considerations include 1) absolute numbers of fish and their spatial and temporal distribution; 2) current abundance in relation to historical abundance and carrying capacity of the habitat; 3) trends in abundance, based on indices such as dam or redd counts or on estimates of recruit-to-spawner ratios; 4) natural and human-influenced factors that cause variability in survival and abundance; 5) possible threats to genetic integrity (e.g., selective fisheries and interactions between hatchery and natural fish); and 6) recent events (e.g., a drought or a change in management) that have predictable short-term consequences for abundance of the ESU.

Additional risk factors, such as disease prevalence or changes in life-history traits, may also be considered in evaluating risk to populations. The BRT used a risk-matrix method to quantify risks in different categories within each ESU. This method is a modification of the risk assessment used in the original Busby et al. (1996) coastwide steelhead status review, but is designed to reflect the four major population viability criteria identified in the NMFS viable salmonid populations (VSP) document (McElhany et al. 2000): abundance, growth rate/productivity, spatial structure, and diversity. These criteria are being used as a framework for ESA recovery planning for salmon and steelhead. Tabulating mean risk scores for each element allowed the BRT to identify the most important concerns for each ESU and to compare relative risk across ESUs and species. The BRT considered these data and other information in making their overall risk assessments. The BRT had access to NMFS final policy on how to consider hatchery fish in ESA viability assessments (NMFS 2005). Following this policy, the BRT explicitly considered both the negative and positive effects of existing hatchery programs on the overall viability of the ESU.

According to the ESA, the determination of whether a species is threatened or endangered should be made on the basis of the best scientific information available regarding its current status, after taking into consideration conservation measures that are proposed or are in place. In this review, we do not evaluate likely or possible effects of conservation measures. Therefore, we do not make recommendations as to whether identified ESUs should be listed as threatened or endangered species, because that determination requires evaluation of factors not considered by us. Rather, we have drawn scientific conclusions about the risk of extinction faced by identified ESUs under the assumption that present conditions will continue (recognizing, of course, that natural demographic and environmental variability is an inherent feature of "present conditions"). Conservation measures will be taken into account by the NMFS Northwest Regional Office in making its listing recommendations.

If it is determined that a listing(s) is warranted, then NMFS is required by law (1973 ESA Sec. 4(a)(1)) to identify one or more of the following factors responsible for the species' threatened or endangered status: 1) destruction or modification of habitat; 2) overutilization by humans; 3) disease or predation; 4) inadequacy of existing regulatory mechanisms; or 5) other natural or human factors. This status review does not formally address factors for decline, except insofar as they provide information about the degree of risk faced by the species in the future.

Puget Sound Steelhead

Previous Determinations

The NMFS has previously received two petitions to list populations of steelhead (anadromous *Oncorhynchus mykiss*) in the Puget Sound region as threatened or endangered "species" under the ESA. The ESA stipulates that, if a petition is found to present substantial information that a listing may be warranted, NMFS must conduct a status review and issue a determination on its findings within one year. Washington Trout (1993) petitioned NMFS on 21 September 1993 for ESA listing of Washington's Deer Creek summer-run steelhead. NMFS determined that Deer Creek summer-run steelhead did not it itself constitute an ESU (NMFS 1994b). On 16 February 1994, Oregon Natural Resources Council and 15 co-petitioners asked NMFS to list all steelhead in Washington (including Puget Sound), Idaho, Oregon, and California as threatened or endangered under the ESA (ONRC et al. 1994). The petitioners identified 178 stocks of steelhead of special concern and included information on stock origin, stock status, and factors affecting their abundance.

In 1994, the NMFS convened a Biological Review Team (BRT) to determine if the 178 stocks of steelhead listed in the ONRC et al. petition constituted one or more distinct "species" as defined by the ESA. Based on an analysis of environmental characteristics (geologic, geographic, and ecological) and steelhead biological (genetic, life-history, and morphometric) characteristics, the BRT identified 15 ESUs for steelhead in Washington, Idaho, Oregon, and California (Busby et al. 1996). A Puget Sound ESU was identified that included steelhead spawning in rivers from the Elwha River to the Nooksack River (Figure 1). The Puget Sound Steelhead ESU was characterized by Busby et al. (1996) as follows:

> Puget Sound--This coastal steelhead ESU occupies river basins of the Strait of Juan de Fuca, Puget Sound, and Hood Canal, Washington. Included are river basins as far west as the Elwha River and as far north as the Nooksack River.
>
> No recent genetic comparisons have been made of steelhead populations from Washington and British Columbia, but samples from the Nooksack River differ from other Puget Sound populations, and this may reflect a genetic transition zone or discontinuity in northern Puget Sound. In life history traits, there appears to be a sharp transition between steelhead populations from Washington, which smolt primarily at age 2, and those in British Columbia, which most commonly smolt at age 3. This pattern holds for comparisons across the Strait of Juan de Fuca as well as for comparisons of Puget Sound and Strait of Georgia populations. At the present time, therefore, evidence suggests that the northern boundary for this ESU coincides approximately with the U.S.-Canada border.

Figure 1. Map of the Puget Sound steelhead ESU, denoting the major summer- and winter-run populations identified by SaSI (2002). Map drawn by Jeremy Davies, Northwest Fisheries Science Center.

Recent genetic data provided by WDFW show that samples from the Puget Sound area generally form a coherent group, distinct from populations elsewhere in Washington. There is also evidence for some genetic differentiation between populations from northern and southern Puget Sound, but the BRT did not consider that ecological or life history differences were sufficient to warrant subdividing this ESU. Chromosomal studies show that steelhead from the Puget Sound area have a distinctive karyotype not found in other regions.

The Puget Sound region is in the rain shadow of the Olympic Mountains and therefore is drier than the Olympic Peninsula; most of the Puget Sound region averages less than 160 cm of precipitation annually, while most areas of the Olympic Peninsula exceed 240 cm (Jackson 1993). Climate and river hydrology change west of the Elwha River (see Weitkamp et al. 1995). The rivers in Puget Sound generally have high relief in the headwaters and extensive alluvial floodplains in the lowlands. Geology and topography are dominated by the effects of the Cordilleran Ice Sheet as evidenced by glacial deposits and the regional geomorphology.

Puget Sound's fjord-like structure may affect steelhead migration patterns; for example, some populations of coho and Chinook salmon, at least historically, remained within Puget Sound and did not migrate to the Pacific Ocean itself (Wright 1968, Williams et al. 1975, Healey 1980). Even when Puget Sound steelhead migrate to the high seas, they may spend considerable time as juveniles or adults in the protected marine environment of Puget Sound, a feature not readily accessible to steelhead from other ESUs.

Most of the life history information for this ESU is from winter-run fish. Apart from the difference with Canadian populations noted above, life history attributes of steelhead within this ESU (migration and spawn timing, smolt age, ocean age, and total age at first spawning) appear to be similar to those of other west coast steelhead. Ocean age for Puget Sound summer steelhead varies among populations; for example, summer steelhead in Deer Creek (North Fork Stillaguamish River Basin) are predominately age-1-ocean, while those in the Tolt River (Snoqualmie River Basin) are most commonly age-3-ocean (WDF et al. 1993).

The Puget Sound ESU includes two stocks that have attracted considerable public attention recently: Deer Creek summer steelhead (North Fork Stillaguamish River Basin) and Lake Washington winter steelhead. Deer Creek summer steelhead were petitioned for listing under the ESA (Washington Trout 1993), but NMFS determined that this population did not by itself represent an ESU (NMFS 1994b). Adult Lake Washington winter steelhead have experienced a high rate of predation by California sea lions (*Zalophus californianus*) below the fish ladder at Hiram M. Chittenden Locks (also known as the Ballard Locks), the artificial outlet of Lake Washington. Deer Creek summer steelhead and Lake Washington winter steelhead were 2 of the 178 stocks identified in the west coast steelhead petition (ONRC et al. 1994).

This ESU is primarily composed of winter steelhead but includes several stocks of summer steelhead, usually in subbasins of large river systems and above seasonal hydrologic barriers. Nonanadromous *O. mykiss* co-occur with the anadromous form in the Puget Sound region; however, the relationship between these forms in this geographic area is unclear.

The West Coast Steelhead BRT, having defined the Puget Sound ESU, considered a variety of information in determining the risk of extinction for this ESU. Their conclusion that the ESU was not presently at risk was based on the following considerations (from Busby et al. 1996):

> The BRT concluded that the Puget Sound steelhead ESU is neither presently in danger of extinction nor likely to become endangered in the foreseeable future. Despite this conclusion, the BRT has several concerns about the overall health of this ESU and about the status of certain stocks within the ESU. Recent trends in stock abundance are predominantly downward, although this may be largely due to recent climate conditions. Yet trends in the two largest stocks (Skagit and Snohomish Rivers) have been upward.
>
> The majority of steelhead produced within the Puget Sound region appear to be of hatchery origin, but most hatchery fish are harvested, and estimates of hatchery fish escaping to spawn naturally are all less than 15% of total natural escapement, except for the Tahuya and Morse Creek/Independents stocks where the hatchery proportion is approximately 50%. We are particularly concerned that the majority of hatchery production originates from a single stock (Chambers Creek), which could increase genetic homogenization of the resource despite management efforts to minimize introgression of the hatchery gene pool into natural populations via separation of hatchery and natural run timing and high harvest rates focused on hatchery runs.
>
> The status of certain stocks within the ESU is also of concern, especially the depressed status of most stocks in the Hood Canal area and the steep declines of Lake Washington winter steelhead and Deer Creek summer steelhead.
>
> These conclusions are tempered by two substantial uncertainties. First, there is very little information regarding the abundance and status of summer steelhead in the Puget Sound region. Although the numbers of summer steelhead have historically been small relative to winter steelhead, they represent a substantially different life history strategy and loss of these fish would diminish the ecological and genetic diversity of the entire ESU. Second, there is uncertainty regarding the degree of interaction between hatchery and natural stocks. Although WDFW's conclusion that there is little overlap in spawning between natural and hatchery stocks of winter steelhead throughout the ESU is generally supported by available evidence, for many basins it is based largely on models and assumptions regarding run timing rather than empirical data.

On 9 August 1996, the NMFS proposed that 10 of the 15 West Coast steelhead ESUs identified be listed under the ESA. NMFS determined that listing was not warranted for four of the remaining five ESUs (Puget Sound, Olympic Peninsula, Southwest Washington, and the Upper Willamette River), while a fifth ESU (Middle Columbia River) was designated as a candidate species (61 FR 41451). On 18 August

1997, two steelhead ESUs (Southern California and Upper Columbia River) were listed by the NMFS as endangered and three steelhead ESUs (Central California Coast, South Central California Coast, and Snake River) were listed as threatened under the ESA (62 FR 43937). NMFS listed the Lower Columbia River and Central Valley steelhead ESUs as threatened on 19 March 1998 (63 FR 1347). The Middle Columbia steelhead ESU and Upper Willamette River steelhead ESU were listed as threatened by NMFS for listing under the ESA on 25 March 1998 (64 FR14517). The Northern California steelhead ESU was listed as threatened on 7 June 2000 (66 FR 17845).

Current Petition to List Puget Sound Steelhead

On 13 September 2004, the NMFS received a petition to list Puget Sound steelhead as endangered or threatened submitted by Sam Wright (Wright 2004). The petition describes several factors that justify a reexamination of the extinction risk for the Puget Sound steelhead ESU. These factors include: declines in steelhead abundances such that "not a single entire river basin, large or small, … had a significant upward short-term trend," and that these declines have occurred under a harvest regime that prohibits the retention of wild (unmarked) adults by recreational anglers. The petition disputed the assertion by WDFW that that winter-run steelhead hatchery stocks (predominately Chambers Creek Hatchery) were substantially spatially separated from natural winter-run steelhead populations and cited studies of hatchery-wild steelhead interactions that substantiate the deleterious impact of hatchery fish on natural reproduction and sustainability. The conclusion of the petitioner was that these factors justify a determination that Puget Sound steelhead are in danger of extinction throughout all or a significant portion of its range or are likely to become so in the foreseeable future.

ESU Determination

The petitioner provided a synopsis of the Puget Sound steelhead ESU definition (Wright 2004) and found no compelling recent information that would justify a re-examination of the ESU boundary identified in Busby et al. (1996).

Artificial Propagation

Two hatchery stocks constitute the majority of steelhead hatchery production in Puget Sound: Chambers Creek winter-run steelhead and Skamania Hatchery summer-run steelhead. The petitioner asserts that hatchery production has increased since the time of the last status review and this increase in production only heightens the risks of hybridization between domesticated hatchery fish and natural fish. Furthermore, the petition references a study by Washington Trout that reports hatchery and natural-origin steelhead are not temporally reproductively isolated, but instead interbreed in areas where they co-occur. Additionally, increased artificial propagation increases the potential for competition between hatchery-origin and natural-origin juveniles, as well as predation on emergent and juvenile natural steelhead by residualized hatchery steelhead.

Viability Analysis

The petitioner provided a review of Puget Sound steelhead viability using the viable salmon population (VSP) criteria described in McElhany et al. (2000). The VSP criteria have provided the basis for risk assessments in recent status review updates.

Abundance—In the 10 years since the previous status review by Busby et al (1996), the abundance of naturally produced steelhead in Puget Sound has decreased at a steady pace. The petition provides recent abundance estimates for those steelhead populations that have been monitored. The petition asserts that steelhead within four geographic regions within Puget Sound—Juan de Fuca Strait, Bellingham Bay, Hood Canal, South Puget Sound—are all approaching functional extinction (i.e., approaching an abundance at which intrinsic biological factors cannot prevent future extinction, even if external threats are removed). In particular, absolute abundances have fallen to levels where density depensation effects are likely and most populations are at risk of extirpation by adverse environmental conditions. The Skagit River was the one basin identified as containing steelhead populations large enough to resist adverse environmental or depensatory forces.

Productivity—Based on the abundance information provided, the petitioner asserts that every basin showed either a significant short- or long-term downward trend. This assertion contrasts with the earlier assessment of Busby et al. (1996), who reported basin-wide trends for Puget Sound that were negative on a short-term basis or were not significantly different from zero. The petition underscored the fact that this decline in productivity has occurred at a time when fishery impacts on naturally produced steelhead presumably declined substantially with the advent of hatchery-only retention in the sports fishery and curtailment of most tribal fisheries.

Diversity—The petitioner reiterated several risk factors identified in Busby et al. (1996). The extensive use of Chambers Creek Hatchery winter-run steelhead and Skamania Hatchery summer-run steelhead throughout the ESU were considered substantial risks to ESU diversity, especially in light of the new information that suggests introgression by the Chambers Creek stock into natural populations. Interspecies hybridization between *O. mykiss* and cutthroat trout (*O. clarki*) is also discussed as a threat to the genetic diversity of the ESU. Studies by Marshall et al. (2004) and Ostberg and Rodriquez (2002) were cited as evidence of widespread hybridization between these two species. However, it is unclear whether this latter hybridization is due to anthropogenic factors or a natural evolutionary process.

Spatial Structure/Connectivity—The petitioner argued that there has been an overall degradation in the spatial structure characteristics of Puget Sound steelhead. In part, this degradation has been due to the loss of connectivity between populations with the decline in abundance for most populations. The petition specifically identifies the loss of connectivity between the Duwamish (Green) and Snohomish rivers due to the near extirpation of steelhead in the Lake Washington and Lake Sammamish watersheds.

Review of Steelhead Life-History Information

General Oncorhynchus mykiss ***Life History***

Of all the Pacific salmonids, *O. mykiss* probably exhibits the greatest diversity in life history throughout its native, geographic range from Kamchatka to southern California. However, even within the confines of Puget Sound and the Strait of Georgia there is considerable life-history variation compared with other salmonid species. Resident *O. mykiss*, commonly called rainbow trout, complete their life cycle completely in fresh water. Anadromous *O. mykiss*, or steelhead, reside in fresh water for their first one to three years before emigrating to the ocean for one to three years. In contrast with other species of Pacific salmon, *O. mykiss* is iteroparous, capable of repeat spawning. Averaged across all West Coast steelhead populations, 8% of spawning adults have spawned previously, with coastal populations having a higher incidence of repeat spawning relative to inland populations (Busby et al. 1996).

There are two major life-history types expressed by anadromous *O. mykiss*, related to the degree of sexual development at the time of adult freshwater entry (Smith 1969, Burgner et al 1992). Stream-maturing steelhead, also called summer-run steelhead, enter fresh water at an early stage of maturation, usually from May to October. These summer-run steelhead migrate to headwater areas and hold for several months prior to spawning in the spring. Ocean-maturing steelhead, also called winter-run steelhead, enter fresh water from November to April at an advanced stage of maturation, spawning from March through June. While there is some temporal overlap in spawn timing between these forms, in basins where both winter- and summer-run steelhead are present summer-run steelhead spawn farther upstream, usually above a partially impassable barrier (Behnke 1992, Busby 1996). In many cases it appears that the summer migration timing evolved to access areas above a series of falls or cascades that presents a velocity barrier to migration during high winter flow months (especially in rain and snow driven basins), but are passable during low summer flows. The winter run of steelhead is the predominant run in Puget Sound, in part because there are relatively few basins in the Puget Sound ESU with the geomorphological and hydrological characteristics necessary to establish the summer-run life history. The summer-run steelhead's extended freshwater residence prior to spawning results in higher prespawning mortality levels relative to winter-run steelhead. This survival disadvantage may explain why winter-run steelhead predominate where no migrational barriers are present (Dan Rawding, WDFW, Vancouver, Washington, pers. commun.) or freshwater migration distances to saltwater are less than 200 km.

Puget Sound Steelhead Life History

There are a number of early descriptions of steelhead in Puget Sound, although inconsistencies in the early classification of salmonids resulted in steelhead apparently being listed under multiple scientific names. Suckley (1858) described the square-tailed salmon, *Salmo truncatus*, from fish captured in the Strait of Juan de Fuca in January and February 1857. Suckley noted that this species is very similar to *S. gairdneri*. It was reported to enter Puget Sound from the middle of autumn and into December. River entry apparently occurred through December and January; these fish were also reported in the Hood Canal in January. The fish was known to the Klallam Tribe as "klutchin" and to the Nisqually Tribe as "Skwowl." Suckley (1858) also reported that this fish did not enter freshwater in large schools as did other salmon, but that the run was more drawn out. In contrast, Suckley (1858) described anther square-tailed salmon, *S. gairdneri*, captured in the Green River but which had a later run timing. The fish, known to the Skagetts [sic] as "yoo-mitch," entered freshwater from in mid-June to August, a run timing that corresponds to existing summer-run steelhead.

In 1900, a study by the Smithsonian Institution reported steelhead begin to returning to fresh water as early as November, but that the principal river fisheries occurred in January, February, and March, when "the fish are in excellent condition" (Rathbun 1900). The average weight for returning steelhead was 3.6 to 6.8 kg (8 to 15 lb.), although fish weighing 11.4 kg (25 lb.) or more were reported. The principal fisheries were in the Skagit River Basin, although in "nearly all other rivers of any size the species seems to be taken in greater or less quantities (Rathbun 1900)." The spawning season of (winter-run) steelhead was described as occurring in the early spring, but possibly beginning in the latter part of winter. The predominant run timing in Puget Sound appears to have been the winter run. Information on summer-run steelhead in Puget Sound is very limited. In fact, in its 1898 report, the Washington State Fish Commission concluded that the Columbia River was "the only stream in the world to contain two distinct varieties of Steel-heads" (Little 1898). Little (1898) did indicate; however, that the winter run of steelhead continued until the first of May and overlapping populations of winter- and summer-run steelhead may have been considered a single run. Evermann and Meek (1898) reported that B.A. Alexander examined a number of steelhead caught near Seattle in January 1897, and that the fish were in various stages of maturation: "a few fish were spent, but the majority were well advanced and would have spawned in a short time."

Much of the early life-history information comes from the collection and spawning of steelhead intercepted at hatchery weirs. The U.S. Fish Commission Hatchery at Baker Lake collected steelhead returning to Baker Lake using gillnets. Fish were collected from 9 March to 8 May, few survived to spawn, and no spawning date was given (U.S.B.F. 1900). Steelhead were spawned at the Quilcene National Fish Hatchery in Hood Canal from 27 February to 7 June 1922 (USBF 1923). Pautske and Meigs (1941) indicated that the steelhead run arrived in two phases: "In the early run the fish are small, averaging 8 or 9 pounds. The later run is composed of fish as large as 16 or 18 pounds." It was unclear whether these phases were distinct runs or different segments of the same run.

Winter-run Steelhead

In general, winter-run, or ocean maturing, steelhead return as adults to the tributaries of Puget Sound from December to April (WDF et al. 1973). Spawning occurs from January to mid-June, with peak spawning occurring from mid-April through May (Table 1). Prior to spawning, maturing adults hold in pools or in side channels to avoid high winter flows.

Steelhead tend to spawn in moderate to high-gradient sections of streams. In contrast to semelparous Pacific salmon, steelhead females do not guard their redds, or nests, but return to the ocean following spawning (Burgner et al. 1992). Spawned-out females that return to the sea are referred to as "kelts."

Summer-run Steelhead

The life history of summer-run steelhead is highly adapted to specific environmental conditions. Because these conditions are not common in Puget Sound, the relative incidence and size of summer-run steelhead populations is substantially less than that for winter-run steelhead. Summer-run steelhead have also not been widely monitored, in part, because of their small population size and the difficulties in monitoring fish in their headwater holding areas. Sufficient information exists for only 4 of the 16 Puget Sound summer-run steelhead populations identified in the 2002 Salmon Steelhead Inventory (SaSI) to determine the population status (WDFW 2002)

Juvenile Life History

The majority of steelhead juveniles reside in fresh water for two years prior to emigrating to marine habitats (Table 2a-c), with limited numbers emigrating as one or three-year old smolts. Smoltification and seaward migration occur principally from April to mid-May (WDF et al. 1972). Two-year-old naturally produced smolts are usually 140-160 mm in length (Wydoski and Whitney 1979, Burgner et al. 1992). The inshore migration pattern of steelhead in Puget Sound is not well understood; it is generally thought that steelhead smolts move quickly offshore (Hartt and Dell 1986).

Ocean Migration

Steelhead oceanic migration patterns are poorly understood. Evidence from tagging and genetic studies indicates that Puget Sound steelhead travel to the central North Pacific Ocean (French et al. 1975, Hartt and Dell 1986, Burgner et al. 1992). Puget Sound steelhead feed in the ocean for one to three years before returning to their natal stream to spawn. Typically, Puget Sound steelhead spend two years in the ocean,

Table 1. Timing of freshwater entry (shaded months) and spawning (letters) for native populations of steelhead (*O. mykiss*) in Puget Sound and the eastern Strait of Juan de Fuca. SSH denotes summer-run and WSH winter-run steelhead. **P** indicates month of peak spawning, and s indicates months when non-peak spawning occurs. Information from WDFW et al. (2002).

Population	Run	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July
Nooksack River	WSH											s	s	s	**P**	s	
Samish River	WSH											s	s	**P**	s	s	
Skagit River	WSH												s	s	**P**	s	
Sauk River	SSH													s	s		
Cascade River	SSH										s	s	s	s			
Stillaguamish River	WSH												s	s	**P**	s	
Deer Creek	SSH													s	s		
SF Stillaguamish	SSH										s	s	s	s			
Snohomish River	WSH												s	**P**	s	s	
NF Skykomish R.	SSH																
Lake Washington	WSH												s	**P**	s	s	
Green River	WSH												s	**P**	s	s	
Puyallup River	WSH												s	**P**	s	s	
Nisqually River	WSH												s	**P**	s	s	
Deschutes River	WSH										s	**P**	s	s			
S. Sound Inlets	WSH											s	P	**P**			
Tahuya River	WSH											s	s	**P**	s		
Skokomish River	WSH											s	s	**P**	s	s	
Dewatto River	WSH											s	s	**P**	s		
Discovery Bay	WSH											s	s	**P**	s	s	
Dungeness River	WSH												s	s	**P**	s	
Morse Creek	WSH											s	s	**P**	s	s	

although, notably, Deer Creek summer-run steelhead spend only a single year in the ocean before spawning (Table 2b-c).[1]

Table 2a. Age structure of Puget Sound steelhead: frequencies of freshwater ages at the time of emigration to the ocean. The frequency in bold indicates the most common age. Reproduced from Busby et al. (1996). Populations in italics are representative of adjacent ESUs.

		Freshwater Age at Migration to Ocean				
Population	Run	1	2	3	4	Reference
Chilliwack River	*WSH*	0.02	**0.62**	0.36	<0.01	Maher and Larkin 1956
Skagit River	WSH	<0.01	**0.82**	0.18	<0.01	WDFW 1994b
Deer Creek	SSH	--	**0.95**	0.05	--	WDF et al. 1993
Snohomish River	WSH	0.01	**0.84**	0.15	<0.01	WDFW 1994b
Green River	WSH	0.16	**0.75**	0.09	--	Pautzke and Meigs 1941
Puyallup River	WSH	0.05	**0.89**	0.06	--	WDFW 1994b
Nisqually River	WSH	0.19	**0.80**	0.01	--	WDFW 1994b
Hoh River	*WSH*	0.03	**0.91**	0.06	--	Larson and Ward 1952

Table 2b. Age structure of Puget Sound steelhead: frequencies of ocean age at the time of first spawning. The frequency in **bold** indicates the most common age. Reproduced from Busby et al. (1996). Populations in italics are representative of adjacent ESUs.

		Ocean Age at First Spawning					
Population	Run	0	1	2	3	4	Reference
Chilliwack River	*WSH*	--	<0.01	**0.50**	0.49	<0.01	Maher and Larkin 1955
Skagit River	WSH	--	--	**0.57**	0.42	0.01	WDFW 1994b
Deer Creek	SSH		**1.00**	**--**	--	--	WDF et al. 1993
Snohomish River	WSH	--	--	**0.57**	0.42	0.01	WDFW 1994b
Green River	WSH	0.02	0.07	**0.66**	0.25	--	Pautzke and Meigs 1941
Puyallup River	WSH	--	--	**0.70**	0.30	--	WDFW 1994b
Nisqually River	WSH	--	--	**0.63**	0.36	0.01	WDFW 1994b
Hoh River	*WSH*	--	0.02	**0.81**	0.17	--	Larson and Ward 1952

[1] Steelhead are typically aged from scales or otoliths based on the number of years spent in fresh water and saltwater. For example, a 2/2 aged steelhead spent 2 years in fresh water prior to emigrating to the ocean, where after 2 years in the ocean the fish returned to spawn.

Table 2c. Age structure of Puget Sound steelhead: frequencies of life-history patterns. Age structure indicates freshwater age/ocean age. Reproduced from Busby et al. (1996). Populations in italics are representative of adjacent ESUs.

		Life History (frequency)				
Population	Run	Primary		Secondary		Reference
Chilliwack River	*WSH*	2/2	0.31	2/3	0.31	Maher and Larkin 1956
Skagit River	WSH	2/2	0.48	2.3	0.33	WDFW 1994b
Deer Creek	SSH	2/1	0.95	3/1	0.05	WDF et al. 1993
Snohomish River	WSH	2/2	0.47	2/3	0.36	WDFW 1994b
Green River	WSH	2/2	0.52	2/3	0.17	Pautzke and Meigs 1941
Puyallup River	WSH	2/2	0.61	2/3	0.28	WDFW 1994b
Nisqually River	WSH	2/2	0.51	2/3	0.28	WDFW 1994b
Hoh River	*WSH*	2/2	0.74	2/3	0.14	Larson and Ward 1952

Genetics—Previous Studies

Busby et al. (1996) presented the results from a number of genetic studies that described the population structure of *O. mykiss* throughout Washington and the Pacific Northwest. Collectively, these studies provided the genetic evidence for the establishment of the 16 steelhead ESUs that currently exist. The following summary will focus on those studies that are relevant to the delineation of the Puget Sound ESU.

Early work by Allendorf (1975) with protein electrophoresis identified two major *O. mykiss* lineages in Washington, the inland and coastal forms that are separated by the Cascade Crest. This pattern also exists to the north in British Columbia (Utter and Allendorf 1977, Okazaki 1984, Reisenbichler et al. 1992). Reisenbichler and Phelps (1989) analyzed genetic variation from 9 populations in Northwest Washington using 19 gene loci. Their analysis indicated that there was relatively little between-basin genetic variability, which may have been due to the extensive introduction of hatchery steelhead throughout the area. Alternatively, Hatch (1990) suggested that the level of variability detected by Reisenbichler and Phelps (1989) may be related more to the geographical proximity of the 9 populations rather than the influence of hatchery fish.

The number and morphology of chromosomes in a fish offers an alternative indicator of differences in lineage. Analysis of chromosomal karyotypes from anadromous and resident *O. mykiss* by Thorgaard (1977, 1983) indicated that fish from the Puget Sound and Strait of Georgia had a distinctive karyotype. In general, *O. mykiss* have 58 chromosomes; however, fish from Puget Sound had between 58 and 60 chromosomes. Further study by Ostberg and Thorgaard (1994) verified this pattern through more extensive testing of native-origin populations.

Phelps et al. (1994) and Leider et al. (1995) reported results from an extensive survey of Washington State anadromous and resident *O. mykiss* populations. Populations from Puget Sound and the Strait of Juan de Fuca were grouped into three clusters of genetically similar populations: 1) Northern Puget Sound (including the Stillaguamish River and basins to the north, 2) south Puget Sound, and 3) the Olympic Peninsula (Leider et al. 1995). Additionally, populations in the Nooksack River Basin and the Tahuya River (Hood Canal) were identified as outliers. Leider et al. (1995) also reported on the relationship between the life-history forms of *O. mykiss*. They found a close genetic association between anadromous and resident fish in both the Cedar and Elwha rivers. Phelps et al. (1994) indicated that there were substantial genetic similarities between hatchery populations that had exchanged substantial numbers of fish during their operation. Within Puget Sound, hatchery populations of winter-run steelhead in the Skykomish River, Chambers Creek, Tokul River, and Bogachiel River show a high degree of genetic similarity. There was also a close genetic association between natural and hatchery populations in the Green, Pichuck, Raging, mainstem Skykomish, and Tolt rivers, suggesting a high level of genetic exchange. On the other hand, there were several distinct naturally sustained steelhead populations in Puget Sound (Cedar River, Deer Creek, North Fork Skykomish, and North Fork Stillaguamish rivers) that appeared to have undergone minimal hatchery introgression.

ESU Determination

ESU Configuration

The BRT received no new information to consider in re-evaluating the current geographic configuration of the Puget Sound steelhead ESU. A recent publication by Beacham et al. (2004) included two Puget Sound steelhead populations in a population genetic analysis of British Columbia and Washington steelhead, but the BRT concluded that these analyses provided no reason to change the ESU's current boundaries.

Resident and Anadromous Life Histories

Several studies (Zimmerman and Reeves 2000, Docker and Heath 2003, McCusker et al. 2000, Pearson et al. 2003) have shown that native resident and anadromous *O. mykiss* within a drainage are closely related, and likely to interbreed at some level. In the period since Busby et al. (1996) last reviewed the status of Puget Sound steelhead, there has been considerable discussion regarding the inclusion of resident *O. mykiss* into ESUs that potentially contain both resident and anadromous life-history forms. An important question has arisen from this discussion: If resident *O. mykiss* are included in an ESU, to what extent does their presence influence the overall viability of the ESU?

In the BRT's 2003 update of the status of listed ESUs of salmon and steelhead (Good et al. 2005), three different categories of interaction were identified that generally reflected the range of geographic relationships between resident and anadromous forms within different watersheds: 1) no obvious physical barriers, either currently or historically, to interbreeding between resident and anadromous forms; 2) long-standing natural barriers (e.g., a waterfall) separate resident and anadromous forms; resident fish can pass downstream but anadromous fish cannot pass upstream; and 3) relatively recent (e.g., within last 100 years) human actions (e.g., construction of a dam without provision for upstream fish passage) separate resident and anadromous forms.

Where there was no obvious physical barrier to interbreeding between the two life-history forms (Category 1), the BRT's default assumption was that resident fish and anadromous fish were part of the same ESU. This assumption was based on empirical studies that show that resident and anadromous *O. mykiss* are typically very similar genetically when they co-occur with no physical barriers to migration or interbreeding. Additional information presented to the Puget Sound steelhead BRT during a 20 June 2005 technical meeting provided additional Puget Sound specific information describing the interbreeding of resident and anadromous *O. mykiss* where no migrational barriers exist (Category 1). In particular, studies on the Cedar River in the Lake Washington watershed in Puget Sound (Marshall et al. 2004) and on the Quileute River on the Olympic Peninsula (J. McMillan presentation to the BRT, 20 June 2005) indicate that resident *O. mykiss* produce outmigrating smolts in these systems. The BRT agreed that, in the Puget Sound ESU where resident and anadromous *O. mykiss* co-occur, there is likely to be interbreeding between the two life-history forms. Some BRT members considered that in some cases resident fish were probably non-migratory male progeny of anadromous parents rather than a separate breeding population. Several BRT members voiced their opinion that resident *O. mykiss* represented one of a number of life-history forms or polymorphisms within a population, and that the relative expression of these life histories in a population was related to environmental variability and demographic conditions. In all of the scenarios described, there was concurrence among BRT members that resident *O. mykiss* had a close biological relationship to anadromous *O. mykiss*. The BRT therefore determined that all naturally produced *O. mykiss* below long-standing man-made or natural barriers, regardless of their life history, were part of the Puget Sound steelhead ESU.

There was some additional discussion by the BRT regarding the status of resident *O. mykiss* above culverts. In general, and in view of widespread culvert failures or removals, it was determined that the majority of culverts do not represent "long-standing" barriers. Culverts may present relatively ephemeral impediments to migration for days, months, or even years, but are unlikely to result in reproductive isolation on a time scale that would lead to substantial divergence of populations above and below them. Moreover, domesticated rainbow trout of hatchery origin are not typically stocked above culverts as a fishery management strategy, which is not the case for reservoirs upstream of dams (see Category 3, below). Therefore, the BRT concluded that *O. mykiss* above culverts are to be included in the ESU in the absence of specific contrary evidence.

Where resident *O. mykiss* exist above a long-standing natural barrier (e.g., Snoqualmie Falls) the BRT did not consider those fish to be part of the ESU (Category 2 fish in Good et al. 2005). These barriers result in nearly complete reproductive isolation, although there is some probability that fish from upstream populations can move downstream past the barriers. Empirical studies show that in these cases the resident fish typically show substantial genetic and life-history divergence from the nearest downstream anadromous populations (cited in Good et al. 2005).

In cases where the resident fish were separated from the anadromous form by relatively recent human actions (Category 3 fish), the 2003 BRT determined that there was insufficient information currently available to establish a default relationship between below-barrier and above-barrier *O. mykiss* populations. The two life-history forms most likely existed without any barriers to interbreeding prior to the establishment of the man-made barrier(s); however, as a result of rapid divergence in a novel environment, or displacement by or introgression from non-native hatchery rainbow trout, these resident populations may no longer represent the evolutionary legacy of the *O. mykiss* ESU (Good et al. 2005). These cases therefore need to be treated on a case by case basis.

Analysis of an Alaskan population of anadromous *O. mykiss* isolated above a man-made barrier for nearly 20 generations suggests that the ability to produce outmigrating smolts can be diminished, but not eliminated over that time frame (Thrower et al. 2004). Furthermore, preliminary results suggest that in this system the marine survival of smolt progeny of resident parents is substantially less than that of smolt progeny of anadromous parents (Thrower and Joyce 2004; F. Thrower presentation to the BRT, 20 June 2005). It is unclear, however, whether or how rapidly (in generations) natural selection might restore anadromous competency to previously residualized fish.

The existence of *O. mykiss* populations above man-made barriers is a potentially important issue for management of the Puget Sound steelhead ESU, given the planned restoration of fish passage in a number of Puget Sound basins through barrier removal or the establishment of trap and haul programs. The BRT discussed the implications of the planned removal of the two Elwha River dams (Elwha and Glines Canyon dams), the initiation of the trap and haul program at Howard Hanson Dam on the Green River, and proposed passage programs at other Puget Sound dams. Restoration activities need to consider the ESU membership of upstream *O. mykiss* populations. The BRT members felt that ESU membership cannot necessarily be determined *a priori*, but rather must be ascertained on a case-by-case basis. The BRT identified ongoing research programs to examine genetic and morphological similarities between *O. mykiss* populations above and below the barriers on the Elwha, Green, and Cedar rivers as examples of the types of efforts necessary to address the issue of ESU membership. Presently, there is insufficient information available to resolve this issue for any of the Category 3 populations in the Puget Sound ESU.

Artificial Propagation of Puget Sound Steelhead

State and federal hatcheries have attempted to propagate steelhead in Puget Sound since 1900. Hatchery rearing techniques developed during the first decades of hatchery operation were not well suited to steelhead, and were only moderately successful with Pacific salmon. In general, during the early 1900s most hatchery-produced steelhead in Puget Sound were reared for only a few days or weeks prior to release (Figure 2). It was not until the 1940s that extended rearing programs were developed for steelhead (Pautzke and Meigs 1940). Crawford (1979) observed that prior to the work of Clarence Pautzke and Robert Meigs, steelhead runs in many streams were reduced by the hatcheries that were attempting to increase their numbers.

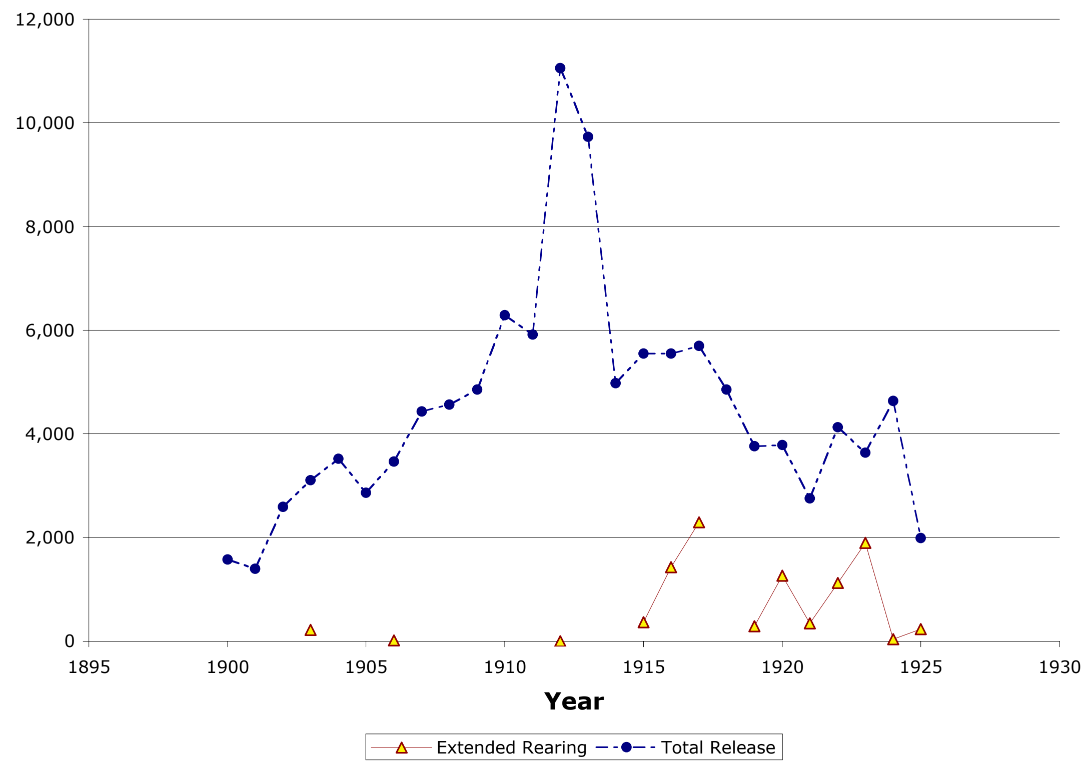


Figure 2. Releases of hatchery propagated steelhead (*O. mykiss*) from state and federal hatcheries in Puget Sound from 1900-1925. The ordinate axis is total number of fish. The duration of culture under extended rearing varied from hatchery to hatchery, but generally continued beyond three months post-emergence and sometimes up to one year post-emergence.

Busby et al. (1996) determined that hatchery fish were widespread, spawn naturally throughout the Puget Sound region, and were largely derived from a single stock (Chambers Creek). The estimated proportion of spawning escapement comprised of hatchery fish ranged from less than 1% (Nisqually River, southern Puget Sound) to 51% (Morse Creek, along the Strait of Juan de Fuca). In general, hatchery proportions were higher in Hood Canal and the Strait of Juan de Fuca than in southern or northern Puget Sound. WDFW, on their SaSI website, has provided information supporting substantial temporal separation between hatchery and natural winter-run steelhead in this region (see also HSRG 2002, 2003, 2004). Given the lack of strong trends in abundance for the major stocks and the apparently limited contribution of hatchery fish to production of the winter-run stocks (Phelps et al. 1979), Busby et al. (1996) determined that hatchery production of winter-run steelhead in Puget Sound contributes little or nothing to the viability of the naturally spawning steelhead populations.

Of the 30 steelhead programs reviewed by the Hatchery Science Review Group (HSRG Recommendations 2002, 2003, 2004), all but three utilized fish derived from either Chambers Creek winter-run steelhead or Skamania summer-run steelhead. The widespread use of these two stocks, accounting for approximately 95% of steelhead hatchery production in the ESU, has raised concerns about their influence on the genetic diversity of the entire ESU.

The Chambers Creek winter-run steelhead stock was founded in 1945 with the trapping of steelhead returning to Chambers Creek (Crawford 1979). Through the use of warmer well water at the South Tacoma Trout Hatchery, the maturation of adults was accelerated to provide an earlier and more uniform spawn timing. Subsequent egg incubation and rearing in warm water, in combination with the development of improved dry feeds, accelerated growth to produce a larger smolt, released at approximately 22.5 g (20 smolts/lb). Throughout the program the earliest maturing fish were selected, resulting in the advancement of average spawn timing from April to December and January. From Chambers Creek Hatchery, winter-run steelhead were transferred to hatcheries throughout Puget Sound, the Washington Coast, and the lower Columbia River. While many of these "satellite" hatcheries may have subsequently incorporated local native winter-run steelhead into their broodstock, genetic analysis by Phelps et al. (1997) indicated that there is a high degree of similarity among these hatchery populations.

The Skamania Hatchery summer-run steelhead stock was founded in the 1950s from wild fish collected in the Washougal and Klickitat rivers, and then transferred to several other facilities where broodstocks are now collected (Howell et al. 1985, Hymer et al. 1992). As with the Chambers Creek winter-run steelhead stock, continued use of the earliest spawning adults resulted in an advancement in spawn timing. In Puget Sound, Skamania Hatchery-origin summer-run steelhead programs continue in the Stillaguamish, Snohomish, and Green River basins. Genetically, hatchery populations founded using Skamania Hatchery summer-run steelhead and feral Skamania Hatchery fish are genetically distinct from Puget Sound populations (Busby et al. 1996, Phelps et al. 1997). Skamania summer-run steelhead are also distinct from Puget Sound steelhead populations in that they possess 58 chromosomes, in contrast to the 60 chromosomes commonly found in Puget Sound *O. mykiss.*

Puget Sound Steelhead Artificial Propagation – New Information

In the nearly 10 years since steelhead artificial propagation programs in Puget Sound were reviewed by Busby et al. (1996) there have been a number of independent studies of these programs, most notably by the Hatchery Scientific Review Group (HSRG 2002, 2003, 2004). Information on steelhead artificial propagation was also submitted by WDFW and the Western Washington Treaty Tribes in preparation for the BRT's review of the petition to list Puget Sound steelhead. This information included recent release levels for winter-run (Figure 3) and summer-run (Figure 4) steelhead in Puget Sound (see also Appendix D).

In general, release levels for steelhead have remained relatively constant over the last two decades. Hatchery-produced winter-run steelhead have been released in nearly every basin in the ESU, with the exception of the Cedar River and some smaller tributaries to Puget Sound and Hood Canal (WDFW 2005). The vast majority of these releases consist of hatchery stocks largely derived from the Chambers Creek winter-run steelhead stock. Releases of hatchery-produced summer-run steelhead have been less widespread and of a lower magnitude. Summer-run steelhead are released predominantly in the Stillaguamish, Snohomish, and Green River

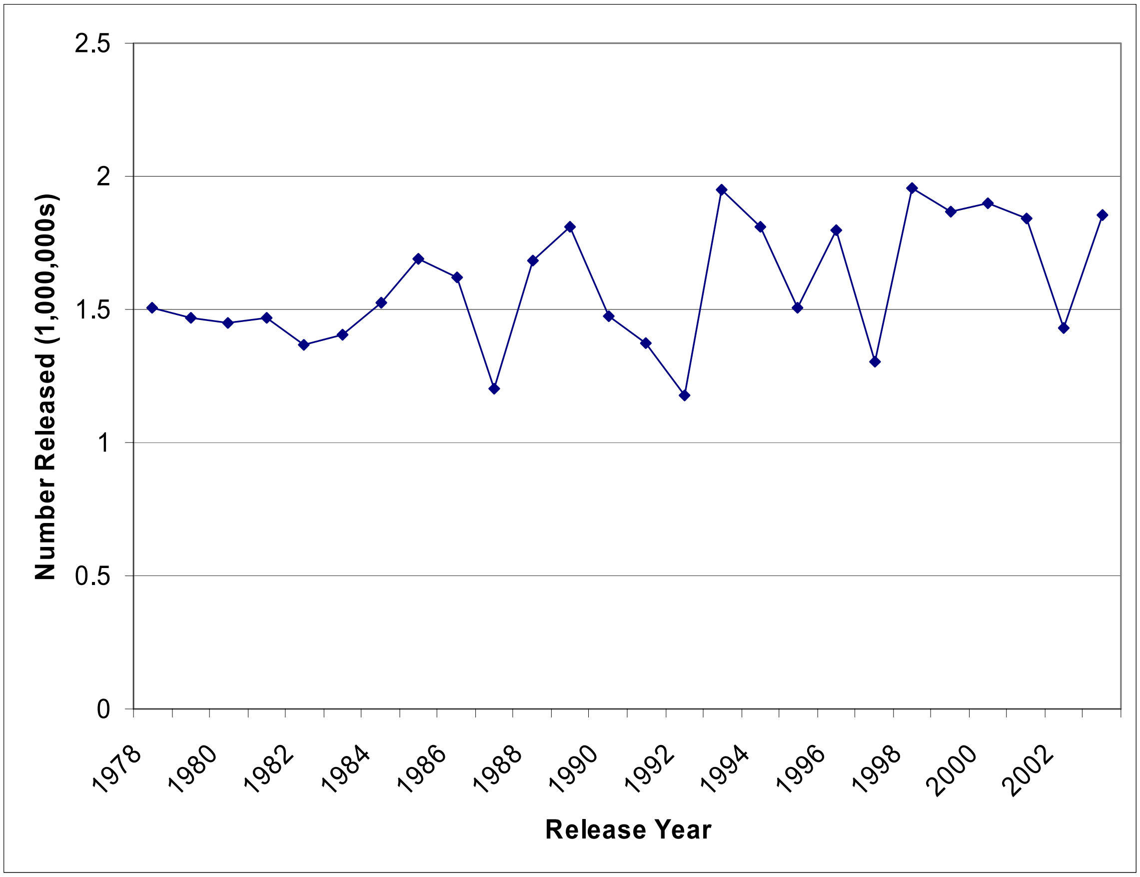


Figure 3. Total releases of winter-run steelhead smolts in the Puget Sound steelhead ESU from 1978 to 2003. Information from WDFW (2005).

basins. All of these releases utilized hatchery stocks that were developed using Skamania Hatchery (Washougal River, Lower Columbia River Steelhead ESU) summer-run stock.

Artificial Propagation – Inclusion of Hatchery Populations in the ESU

Prior to the meeting of the Puget Sound steelhead BRT, the Salmon/Steelhead Hatchery Assessment Group (SSHAG) was convened to review the relationships of steelhead hatchery populations to the Puget Sound ESU. SSHAG reviewed the stock histories for 25 hatchery programs. Hatchery stocks were assigned to one of four categories depending on the relationship between the hatchery population and the naturally produced populations within the ESU (see Appendix B, Table B-1). Briefly, Category 1 hatchery populations have a close genetic and life-history affinity to local naturally produced populations; Category 2 stocks are no more than moderately diverged from the local natural populations; Category 3 stocks are substantially diverged from these local natural populations; and Category 4 hatchery populations are derived from out-of-ESU stock sources or had undergone “extreme” divergence from the local natural populations (see Appendix B). SSHAG based its assessments on the hatchery broodstock

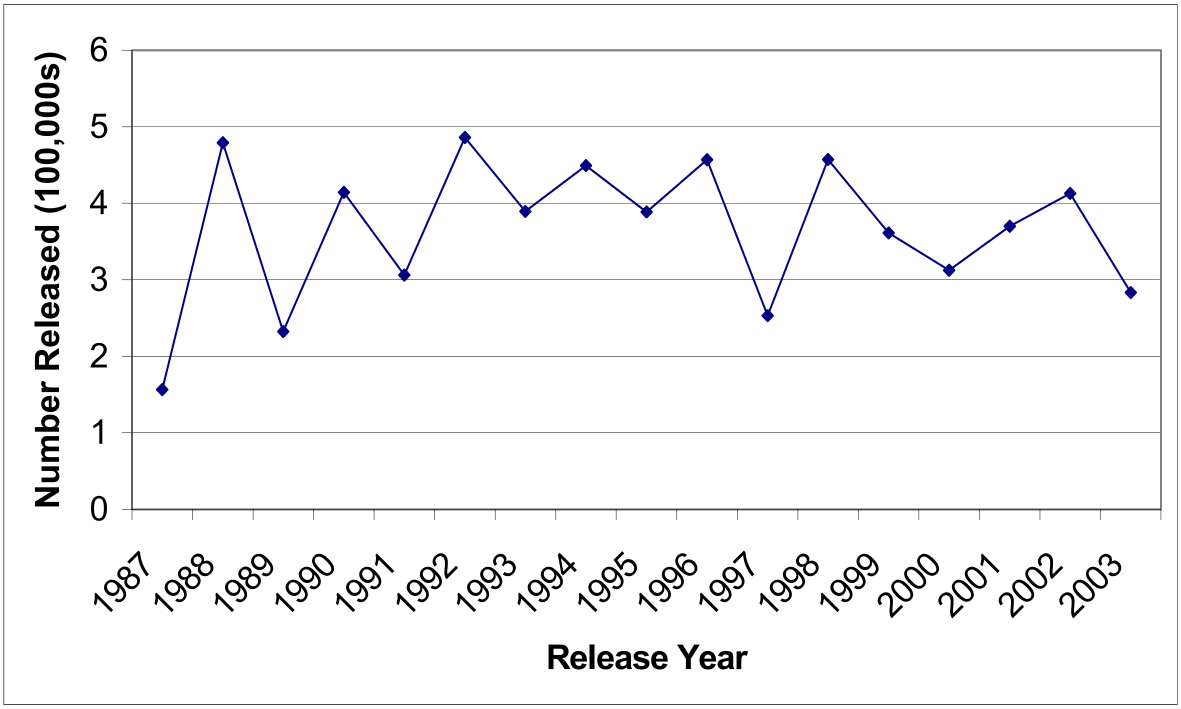


Figure 4. Total releases of summer-run steelhead smolts in the Puget Sound steelhead ESU from 1987 to 2003. Information from WDFW (2005).

histories, which contain information on stock transfers, hatchery practices, and genetic and life-history information where available (Appendix C).

Guidance provided by NMFS Northwest Region indicated that the BRT should consider "hatchery fish with a level of genetic divergence between hatchery stocks and the local natural populations that is no more than what would be expected between closely related populations within the ESU" as appropriate for inclusion in the ESU (Lohn 2005). This level of divergence would include both Category 1 and 2 hatchery populations.

The BRT was presented with the findings of the SSHAG group (Table 3), which recommended only three hatchery stocks for inclusion in the Puget Sound steelhead ESU: Lake Washington winter-run steelhead, Green River natural winter-run steelhead, and Hamma Hamma winter-run steelhead. In the resulting discussion, the BRT excluded the Lake Washington winter-run steelhead "stock" from inclusion, because the program had been unable to acquire broodstock for the past six years and therefore this stock currently does not exist. The remaining hatchery stocks were all derived from one of two sources: 1) Chambers Creek winter-run steelhead, or 2) Skamania Hatchery summer-run steelhead. The majority of the BRT concluded that the Chambers Creek stock and its derivatives were Category 3, and the Skamania stock and its derivates were all Category 4 (Table 3). Some members argued that the Chambers Creek stock and its derivatives should also be considered a Category 4 population because of the substantial changes that this population had undergone under hatchery domestication. This view

Table 3. Hatchery categorization assignment by the Salmon Steelhead Hatchery Assessment Group (SSHAG) for steelhead hatchery programs releasing fish in Puget Sound. Hatchery categorization was based on the average (rounded to nearest integer) of the allocation votes. SSH, summer-run steelhead; WSH, winter-run steelhead.

Hatchery Stock	Hatchery Category
Chambers Creek WSH	3
Skamania Hatchery SSH	4
Regional Egg Pool WSH	3
Bogachiel Hatchery WSH	3
Nooksack River Hatchery WSH	3
Whatcom Creek Hatchery WSH	3
Samish River Hatchery WSH	3
Skagit River Hatchery WSH	3
Stillaguamish Hatchery WSH	3
North Fork Stillaguamish SSH	4
South Fork Stillaguamish SSH	4
Snohomish River Hatchery WSH	3
Snohomish River Hatchery SSH	4
Lake Washington WSH[1]	1
Green River Natural WSH	2
Green River Hatchery WSH	3
Green River Hatchery SSH	4
Puyallup River Hatchery WSH	3
White River Hatchery WSH	3
Deschutes River Hatchery WSH	3
Hamma Hamma River WSH	2
Hood Canal Hatchery WSH	3
Dungeness Hatchery WSH	3
Morse Creek Hatchery WSH	3
Elwha Hatchery WSH	3

[1]When it existed. Based on the information available, the BRT concluded that few if any fish from this stock currently exist.

was supported by comments received from WDFW that hatchery-derived winter-run steelhead have not contributed to natural production as a result of poor spawning success. Genetic analysis by Phelps et al. (1997) indicated that, in many larger river basins, little—if any—detectible influence was evident from many years of Chambers Creek hatchery winter-run steelhead introductions. This result suggests a large degree of reproductive divergence between hatchery and wild winter-run fish. In either case, the BRT concluded that none of Chambers Creek or Skamania derived stocks is part of the Puget Sound steelhead ESU.

The "Extinction Risk" Question

Risk Assessment Approach

In its risk assessment of the current Puget Sound steelhead ESU, the BRT considered a variety of information in evaluating the level of risk faced by the Puget Sound steelhead ESU. It should be noted that the BRT for the Puget Sound steelhead ESU included scientists representing three major federal agencies involved in natural resource management and several of these with considerable expertise in steelhead biology. The information considered in their risk evaluation included magnitudes and trends in abundance of naturally spawning steelhead (adult counts, redd counts, smolt counts, juvenile densities, relative abundance of hatchery and naturally produced fish, and catch statistics), estimates of steelhead productivity (e.g., recruits per spawner data), the distribution and size of summer- and winter-run steelhead populations in the ESU, steelhead harvest rates, releases of hatchery *O. mykiss* in the ESU, the occurrence of resident *O. mykiss* (both native and non-native) in the ESU, recent management changes, and environmental risk factors.

The BRT's analyses of these data included evaluations of abundance of naturally produced fish and overall abundance, longer-term and shorter-term trends in escapement and run size, estimates of recruits per spawner and long-term population growth rate, and age structure.

Viable Salmon Population (VSP) Approach to Risk Analysis

In recent status review updates for Pacific salmon and steelhead (Good et al. 2005), BRTs have adopted a risk assessment method that has been used for Pacific salmon recovery planning and is outlined in the viable salmonid populations (VSP) report (McElhany et al. 2000). In this approach, risk assessment is addressed first at the population level, then at the overall ESU level.

In this approach, individual populations are assessed according to the four population viability criteria: abundance, growth rate/productivity, spatial structure, and diversity. The condition of individual populations is then summarized on the ESU level, and larger-scale issues are considered in evaluating the status of the ESU as a whole. These larger-scale issues include total number of viable populations, geographic distribution of these populations (to ensure inclusion of major life-history types and to buffer the effects of regional catastrophes), and connectivity among these populations (to ensure appropriate levels of gene flow and recolonization potential in case of local extirpations). These considerations are reviewed in McElhany et al. (2000).

The revised risk matrix (Table 4) integrates the four major population viability criteria (abundance, productivity, spatial structure, and diversity) directly into the risk assessment process. After reviewing all relevant biological information for the ESU, each BRT member assigns a risk score (see below) to each of the four population viability criteria. The scores are tallied and reviewed by the BRT before making its overall risk assessment. Although this process helps to integrate and quantify a large amount of diverse information, there is no simple way to translate the risk matrix scores directly into an assessment of overall risk. For example, simply averaging the values of the various risk factors would not be appropriate; an ESU at high risk for low abundance would be at high risk even if there were no other risk factors.

Scoring Population Viability Criteria—Risks for each population viability factor are ranked on a scale of 1 (very low risk) to 5 (very high risk):

1. *Very Low Risk.* Unlikely that this factor contributes significantly to risk of extinction, either by itself or in combination with other factors.

2. *Low Risk.* Unlikely that this factor contributes significantly to risk of extinction by itself, but some concern that it may, in combination with other factors.

3. *Moderate Risk.* This factor contributes significantly to long-term risk of extinction, but does not in itself constitute a danger of extinction in the near future.

4. *High Risk.* This factor contributes significantly to long-term risk of extinction and is likely to contribute to short-term risk of extinction in the foreseeable future.

5. *Very High Risk.* This factor by itself indicates danger of extinction in the near future.

Recent Events—The "recent events" category considers events that have predictable consequences for ESU status in the future but have occurred too recently to be reflected in the population data. Examples include a climatic regime shift or El Nino event that may be anticipated to result in increased or decreased predation in subsequent years. This category is scored as follows:

++ : expect a strong improvement in status of the ESU;
+ : expect some improvement in status;
0 : neutral effect on status;
- : expect some decline in status;
-- : expect strong decline in status.

Table 4. Risk evaluation sheet for the Puget Sound steelhead ESU.

Risk category	**Score**
Abundance[1] *Comments*	
Growth and Productivity[1] *Comments*	
Diversity[1] *Comments*	
Spatial Structure and Connectivity[1] *Comments*	
Recent Events[2]	

[1] *Rate overall risk for each VSP category on a 5-point scale (1-very low risk; 2-low risk; 3-moderate risk; 4-moderate/high risk: 5-high risk)*
[2] *Recent events are rated from a double plus (++) strong benefit to double minus (--) strong detriment.*

The BRT's analysis of overall risk to the ESU used categories that correspond to definitions in the ESA: in danger of extinction, likely to become endangered in the foreseeable future, or neither. (These evaluations do not consider protective efforts, and therefore are not recommendations regarding listing status.) The overall risk assessment reflected professional judgment by each BRT member. This assessment was guided by the results of the risk matrix analysis as well as expectations about likely interactions among factors. For example, a single factor with a "high risk" score might be sufficient to result in an overall score of "in danger of extinction," but a combination of several factors with more moderate risk scores could also lead to the same conclusion.

To allow for uncertainty in judging the actual risk facing the ESU, the BRT adopted a "likelihood point" method, often referred to as the FEMAT method because it is a variation of a method used by scientific teams evaluating options under President Clinton's Forest Plan (Forest Ecosystem Management: An Ecological, Economic, and Social Assessment Report of the Forest Ecosystem Management Assessment Team, or FEMAT). In this approach, each BRT member distributes ten likelihood points among the three ESU risk categories, reflecting their opinion of how likely that category correctly reflects the true ESU status. Thus, if a member were certain that the ESU was in the "not at risk" category, he or she could assign all ten points to that category. A reviewer with less certainty about ESU status could split the points among two or even three categories. This method has been used in all status review updates for anadromous Pacific salmonids since 1999.

Historical Abundance Estimates

Estimates of historical steelhead abundance in Puget Sound have largely been based on catch records. There are a number of considerations that need to be taken into account to convert catch data into run size estimates. First, during the late 1800s and early 1900s Chinook salmon (*Oncorhynchus tshawytscha*) was the preferred species for canning. Secondly, steelhead have a protracted run time relative to Chinook salmon and do not tend to travel in large schools making them less susceptible to harvest. Finally, winter-run steelhead return from December through March when conditions in Puget Sound and the rivers that drain into it are not conducive to commercial fishing operations.

The earliest commercial fisheries catch records, from 1889, indicate that 41,168 kg (90,570 lb) of steelhead were caught in the Puget Sound District (Rathbun 1900). Rathbun (1900) indicated that steelhead were being targeted by fishermen because the winter run occurred at a time when salmon fisheries were at a seasonal low. Assuming an average weight of 5.5 kg (12 lb), the catch would represent 7,548 steelhead. Analysis of the catch records from 1889 to 1920 (Figure 5) indicates that the catch peaked at 163,796 steelhead in 1895. Using a harvest rate range of 30-50%, the estimated peak run size for Puget Sound would range from 327,592–545,987 fish. The majority of the harvest occurred in terminal fisheries (i.e., gill nets or pound nets) in Skagit, Snohomish, King, and Pierce Counties (Cobb 1911), which would suggest that there was little inclusion of Fraser River steelhead in these catch estimates. By 1898, the Washington State Fish Commissioner noted, "The run of this class of fish in the state on the whole has greatly depreciated, and the output for the present season from the best information possible is not fifty percent of what it was to or three years ago. Very little has been done

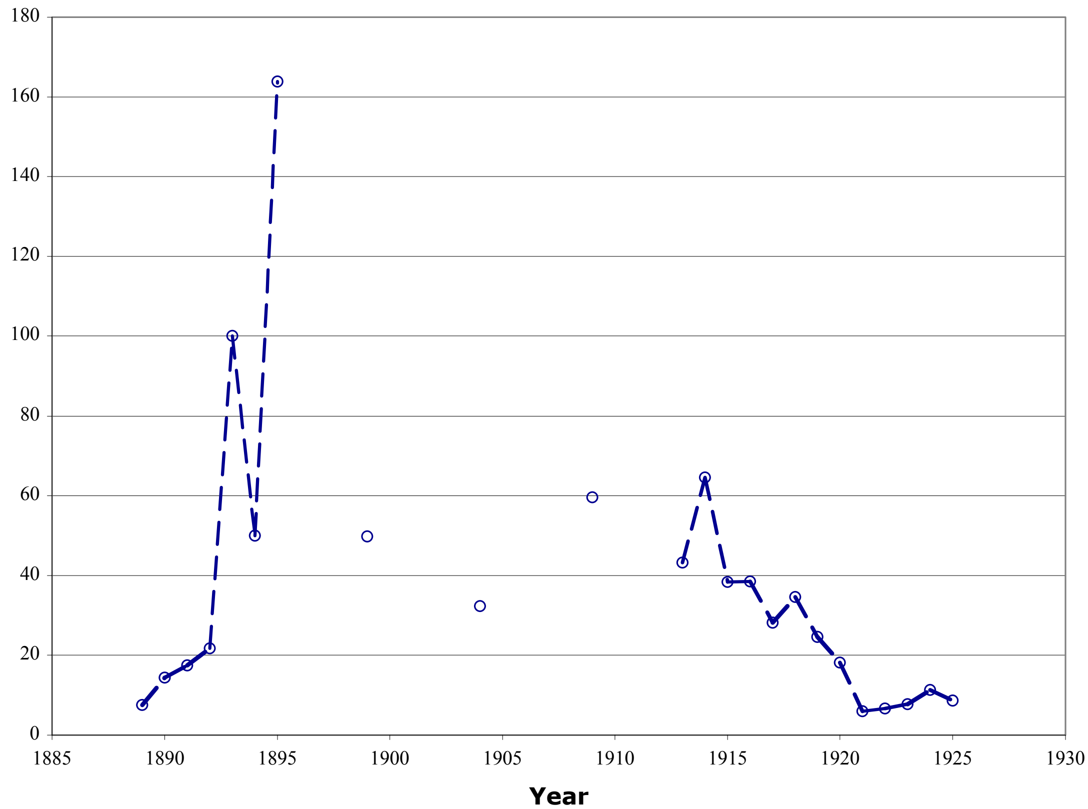


Figure 5. Harvest of steelhead in Puget Sound (1889-1925). The y-axis is total catch in number of fish. In years without data points harvest was reported as a combined salmon/steelhead harvest. Data from Washington Department of Fisheries Annual/Biannual Reports (1890-1920), Rathbun (1900), Wilcox (1902), and Cobb (1911).

towards the protection of this class of salmon…" (Little 1898). Catches continued to decline from 1900 through the 1920s (Figure 5). The management of steelhead was ultimately transferred to the newly formed Washington Department of Game in 1921. In 1925, the Washington State Legislature classified steelhead has a game fish, but only above the mouth of any river or stream (WDFG 1928). Commercial harvest of steelhead in Puget Sound fell to levels generally below 10,000 fish. In 1932, the newly formed Washington State Game Commission prohibited the commercial catch, possession or sale of steelhead (Crawford 1979). After 1932, estimates of Puget Sound steelhead run size were based on sportfisher catch records and spawning ground surveys.

Historical Distribution

Steelhead are found in most every accessible larger tributary to Puget Sound and the eastern Strait of Juan de Fuca. A survey of the Puget Sound District in 1929 and 1930, which did not include Hood Canal (Appendix A), identified steelhead in every major basin except the

Deschutes River (WDFG 1932). The propensity for steelhead to spawn in side channels and tributaries during winter and spring months when flows are high and visibility is low would likely have resulted in an under-reporting of steelhead sightings. Additionally, by the late 1920s steelhead abundance had already undergone significant declines and many marginal or ephemeral populations may have already disappeared.

Recent Abundance Estimates – Through 1996

Total steelhead run size (catch and escapement) for Puget Sound in the early 1980s can be calculated from estimates in Light (1987) to be approximately 100,000 winter-run and 20,000 summer-run fish. Light provided no estimate of hatchery proportions specific to Puget Sound streams, but for Puget Sound and coastal Washington combined, he estimated that 70% of steelhead in ocean runs were of hatchery origin. The percentage in escapement to spawning grounds would be substantially lower due to differential harvest and hatchery rack returns.

In the 1990s the total run size for major stocks in this ESU was greater than 45,000, with total natural escapement of about 22,000. Busby et al. (1996) estimated 5-year average natural escapements for streams with adequate data range from less than 100 to 7,200, with corresponding total run sizes of 550-19,800. Nehlsen et al. (1991) identified nine Puget Sound steelhead stocks at some degree of risk or concern. WDF et al. (1993) considered 53 stocks within the ESU, of which 31 were considered to be of native origin and predominantly natural production. Their assessment of the status of these 31 stocks was 11 healthy, 3 depressed, 1 critical, and 16 of unknown status. Their assessment of the status of the remaining (not native/natural) stocks was 3 healthy, 11 depressed, and 8 of unknown status.

Of the 21 populations in the Puget Sound ESU reviewed by Busby et al. (1996), 17 had declining and 4 increasing trends, with a range from 18% annual decline (Lake Washington winter-run steelhead) to 7% annual increase (Skykomish River winter-run steelhead). Eleven of these trends (9 negative, 2 positive) were significantly different from zero. These trends were for the late-run naturally produced component of winter-run steelhead populations; no adult trend data were available for summer-run steelhead. Most of these trends were based on relatively short data series. The two basins producing the largest numbers of steelhead (Skagit and Snohomish rivers) both had modest overall upward trends at the time of the Busby et al. (1996) report.

There are substantial habitat blockages by dams in the Skagit and Elwha River basins, and minor blockages, including impassable culverts, throughout the region. The Washington State Salmon and Steelhead Stock Inventory (SASSI) (WDF et al. 1993) appendices noted habitat problems, including flooding, unstable soils, and poor land management practices, for most stocks in this region. In general, habitat has been degraded from its pristine condition, and this trend is likely to continue with further population growth and resultant urbanization in the Puget Sound region. Because of their limited distribution in upper tributaries, summer-run steelhead may be at higher risk than winter-run steelhead from habitat degradation in larger, more complex watersheds.

New Information

New abundance, productivity, diversity, and spatial structure information on steelhead populations in the Puget Sound ESU and neighboring regions was compiled by staff of the NWFSC. Additional information and analyses were submitted by co-managing agencies (State and Tribal), non-governmental organizations, and members of the public. This information was presented in a number of different formats: anecdotal descriptions, genetic analyses, weir/dam counts, spawning ground spawner counts, redd counts, and harvest estimates.

Comments Received

In a joint communication, the National Wildlife Federation, American Rivers, and Trout Unlimited (Moryc et al. 2005), underscored the issues put forth in the petition submitted to NMFS by Wright (2004). Primarily, they pointed out that the two largest steelhead producing basins (the Skagit and Snohomish rivers) that had been highlighted as stable in the 1996 NMFS Status Review (Busby et al. 1996) no longer had stable growth trends, but have displayed negative trends in abundance since 1996. In spite of the cessation of directed harvest on wild (unmarked) steelhead in most of Washington's basins, naturally produced populations have continued to decline. Moryc et al. (2005) suggested that the underlying cause for these declines has been habitat degradation (hydropower dams, floodplain development, water withdrawals, and logging). They recommended that NMFS list Puget Sound steelhead as threatened or endangered.

An analysis of stock-recruit relationships for the five major winter-run steelhead populations was submitted to NMFS by Nick Gayeski for Washington Trout (Gayeski 2005). For all five populations (the Skagit, Stillaguamish, Snohomish, Puyallup, and Nisqually rivers), Gayeski (2005) calculated a general declining trend in abundance. Similarly, spawner-recruit relationships were negative, indicating a steady decrease in productivity beginning the late 1980s and early 1990s (further analysis of the Gayeski report can be found in the Risk Assessment Summary section below). Based on the analysis of the ESU's five largest populations, Gayeski (2005) concluded that the ESU should be listed as threatened.

Desmond Wiles submitted a letter supporting the petition to list steelhead in Puget Sound under the ESA (Wiles 2005). The letter emphasized the dramatic decline in numbers of "wild" steelhead and the current lifting of the moratorium on taking "wild" (unmarked) steelhead. Issues relating to harvest and hatchery management were put forth in a letter from Fred Habenicht (Habenicht 2005). In general, Mr. Habenicht believed that the steelhead populations on Washington's coast and along the Strait of Juan de Fuca were stable, although recently the Elwha and Bogachiel River runs of winter-run steelhead appeared to be depressed. He discouraged the continued use of hatchery releases from "a few select sources" and supported the development of local broodstocks of steelhead as the source for hatchery releases. Mr. Habenicht was concerned that the use of early returning steelhead had compressed the current fishing season into a 4-6 week time frame and limited the harvest opportunities for steelhead retention. In addition, the letter suggested that tribal fisheries and sea lion predation were causal factors in the decline of steelhead in steelhead populations along the coast and the Strait of Juan de Fuca, rather than habitat degradation or sport fisheries.

Summary of Major Risks and Status Indicators

The BRT considered the major risk factors facing Puget Sound steelhead to be widespread declines in abundance and productivity for most natural steelhead populations in the ESU, including those in Skagit and Snohomish rivers, previously considered strongholds for steelhead in the ESU; the low abundance of several summer run populations; and the sharply diminishing abundance of some steelhead populations, especially in south Puget Sound, Hood Canal, and the Strait of Juan de Fuca. Continued releases of "out of ESU" hatchery fish from Skamania-derived summer-run and Chambers Creek-derived winter-run stocks were a major diversity concern. Although information on genetic and ecological interactions between natural- and hatchery-origin steelhead within specific Puget Sound populations is largely unavailable, studies conducted elsewhere (e.g., Kalama River, lower Columbia River, Forks Creek, and Willapa River) indicate that hatchery impacts can be substantial, even when mean individual performance of hatchery-origin fish is poor, because of the large numbers of returning hatchery-origin adults that significantly outnumber natural-origin adults. Similarly, despite the divergence in run and spawn times between hatchery-origin and natural-origin winter-run steelhead, the potential for interbreeding effects is still considerable given the large number of returning hatchery fish and the small number of natural-origin fish. At present, the major threat from hatcheries to Puget Sound steelhead comes from past and present hatchery practices involving hatchery stocks that were either founded outside the ESU or have undergone extensive hatchery domestication (see discussion above).

The BRT concluded that it was not possible at present to fully evaluate the contributions resident fish make to ESU viability. Indeed, obtaining a better understanding of how resident fish contribute to steelhead viability appears to be a critical question for future research. Nevertheless, based on the information available, a majority of BRT members concluded that resident *O. mykiss*, in general, constitute a minor component of the Puget Sound ESU, and that the contribution of resident fish to overall abundance and productivity of the ESU is likely to be small, due to relatively low numbers of resident fish and lack of evidence for resident populations that are demographically independent from anadromous populations in the same watersheds. This issue is discussed more fully below.

Inclusion of Resident *O. mykiss* in the Risk Analysis

In evaluating whether to include resident *O. mykiss* in an ESU, the BRT must consider the effect of these resident fish on the viability of the entire ESU. This task is especially difficult given that little or no information is available about the abundance and distribution of resident fish, or about the extent and nature of their interactions with anadromous populations. The 2003 BRT incorporated information about resident populations into their analyses of the four VSP criteria and their assessments of extinction risk for *O. mykiss* ESUs (Good et al. 2005). In several ESUs, Good et al. (2005) concluded that the presence of relatively numerous resident populations reduced risks to ESU abundance. However, there is considerable scientific uncertainty regarding the potential of the resident form to contribute to the ESU productivity, spatial structure/connectivity and diversity of *O. mykiss* ESUs (Varanasi 2004). Good et al. (2005) underscored the importance of the anadromous life-history form in reducing risks to these latter three VSP parameters, and thus in contributing to a viable *O. mykiss* ESU in-total. Although there is the potential for resident populations to generate anadromous migrants, it may be short-lived if the reproductive success of anadromous offspring is low. Finally, the BRT concluded that if the anadromous life-history form in an ESU is extirpated or critically depressed, it is unlikely that the resident life-history form is capable of maintaining the productivity, connectivity, and diversity necessary for a viable *O. mykiss* ESU (NMFS 2003).

Subsequent to the conclusions of the 2003 BRT, NMFS has solicited opinions from two expert panels to review the issue of viability in ESUs that contain both resident and anadromous *O. mykiss*. The independent Recovery Science Review Panel (RSRP) identified anadromy as "an evolutionarily significant component of *O. mykiss* diversity" (RSRP 2004). In their review of available information they concluded that "resident populations by themselves should not be relied upon to maintain long-term viability of an ESU." Similarly, the Independent Scientific Advisory Board (ISAB) found that the long term consequences of the extirpation of a major life-history form would have deleterious consequences on the entire ESU (ISAB 2005):

> To be viable an ESU needs more than simple persistence over time; it needs to be in an ecologically and evolutionarily functional state. Evaluation of ESU viability should not only rest on the numbers of component populations or on the abundance and productivity of those individual populations, but also should be based on the integration of population dynamics within the ecosystem as a whole. This concept of ESU viability does not accommodate the loss of populations or the anadromous or resident life-history form from any given ESU, because that loss would represent a loss in diversity for the ESU that would put its long-term viability at risk.

Where both life-history forms are present, the ISAB considered that the resident forms contribute to the overall abundance and diversity of an ESU, but were unsure of the contribution by resident fish to connectivity and spatial structure. Overall, the presence of both resident and anadromous life-history forms is "critical for conserving the diversity of steelhead/rainbow trout populations and, therefore, the overall viability of ESUs."

In a review of currently listed steelhead ESUs, the Northwest Fisheries Science Center (NWFSC) concluded "None of these ESUs is likely to persist in-total into the foreseeable future because substantial parts of the ESUs are at risk of extinction (Varanasi 2004)." The NWFSC review supported the 2003 BRT conclusions that the ESU were at risk of extinction, now or in the foreseeable future, because the anadromous life history represented a "significant portion of the species 'range', such that its loss is a direct threat to the ESU (Varanasi 2004)."

Puget Sound Steelhead BRT Conclusions

The BRT members believed that the persistence of resident fish in the ESU below long-standing barriers is likely to reduce imminent risk of extinction, but that anadromy is necessary for the long-term persistence of the ESU. Threats to the ESU from loss of the anadromous form include lower productivity and resilience and greater risk of catastrophic loss. Whether the resident form contributes to ESU viability through productivity, spatial structure, and diversity remains unknown, although evidence is growing from several studies that the resident form can retain the genetic basis for anadromy over periods of several decades or more. However, whether resident fish above barriers produce seaward migrants in sufficient numbers to buffer demographic stochasticity substantially in small steelhead populations is not known, either. Because this potential may be short lived if selection against migrants in a resident population is sufficiently strong, the BRT concluded that resident populations are unlikely to significantly reduce the risk of extinction of anadromous populations over the long term.

In the Puget Sound ESU, resident *O. mykiss* are probably associated with many, if not most, of the steelhead populations. Unfortunately, little information and no quantitative abundance or trend data on these residents were available to the BRT for review. Although most BRT members agreed that residents are likely to provide some demographic benefit to steelhead if reproductive connectivity between these forms is sufficient, many also concluded that resident fish appear to be a minor component of *O. mykiss* productivity in the Puget Sound ESU and are not likely to contribute substantially to metapopulation dynamics in these mixed systems. Most of the information relevant to this question is from the Cedar River, where research is ongoing on resident and anadromous fish below and above Landsberg Dam, opened to steelhead migrating upstream in 2002, after decades of isolation. The Cedar River study indicated that sympatric anadromous and resident *O. mykiss* in the system are very similar genetically, but a somewhat more distant relationship existed between *O. mykiss* above and below the barrier (Marshall et al. 2004). It also appeared that resident fish may be contributing to the smolt outmigration, a pattern also observed in the Quileute River on the Olympic Peninsula (presentation by J. McMillan to the BRT, 20 June 2005). The BRT members thought that these studies are central to understanding the relationship between resident and anadromous fish, although some BRT members were concerned that the highly disturbed nature of the Cedar River, which was diverted from the Duwamish River in the early 1900s, may restrict this study's relevance to *O. mykiss* in other river basins.

The BRT noted that resident *O. mykiss* tend to occur as large, self-sustaining populations only where there are major hydrological modifications of the watersheds (e.g., in the Cedar River in the Puget Sound ESU, or upstream from dams, above barriers in the Sacramento-San Joaquin River elsewhere). Rivers west of the Cascade Mountains rarely support resident rainbow trout populations unless the watersheds have been significantly modified, and resident native populations appear to be relatively rare above natural barriers.

The BRT members unanimously believed that the loss of anadromy represents a substantial threat to viability in a mixed ESU. The presence of resident fish is likely to reduce long-term extinction risk only when this form maintains the ability to express the natural range of life-history variation in this species, including anadromy. Even though resident populations might persist if anadromous fish are lost from a population, the contribution of resident populations depends on whether the genetic basis of anadromy is maintained in the resident form. This is not yet known for any Puget Sound *O. mykiss* population.

Habitat Conditions

Habitat utilization by steelhead has been most dramatically affected by a number of large dams in basins to Puget Sound. In addition to eliminating accessibility to habitat, dams affect habitat quality through changes in river hydrology, temperature profile, downstream gravel recruitment, and the movement of large woody debris.

Many of the lower reaches of rivers and their tributaries in Puget Sound have been dramatically altered by urban development. Urbanization and suburbanization have resulted in the loss of historical land cover in exchange for large areas of imperious surface (buildings, roads, parking lots, etc.). The loss of wetland and riparian habitat has dramatically changed the hydrology of many urban streams, with increases in flood frequency and peak flow during storm events and decreases in groundwater driven summer flows (Moscrip and Montgomery 1997, Booth et al. 2002, May et al. 2003). Flood events result in gravel scour, bank erosion, and sediment deposition. Land development for agricultural purposes has also altered the historical land cover; however, because much of this development took place in river floodplains, there has been a direct impact on river morphology. River braiding and sinuosity have been reduced through the construction of dikes, hardening of banks with riprap, and channelization of the mainstem. Constriction of the river, especially during high flow events increases likelihood of gravel scour and the dislocation of rearing juveniles. Side channels are spawning habitat for steelhead and other salmonids. Additionally, side channel areas provide juvenile rearing habitat, especially overwintering habitat (Beechie et al. 2001, Collins and Montgomery 2002, Pess et al. 2002).

There are two major dams in the Nooksack Basin, the Nooksack Falls power plant diversion dam (1906) above the impassable Nooksack Falls (RKm 104.6) and the water diversion dam (1960) on the Middle Fork Nooksack River (RKm 11.6). The Nooksack Falls project is upstream of an inaccessible falls and has been out of operation since a fire in 1997; however, there is concern that renewed operation may alter natural flows. The water diversion dam on the Middle Fork Nooksack River currently prevents upstream access to historical steelhead habitat; furthermore, the dam diverts a considerable proportion of the summer flow to Lake Whatcom for eventual use by the City of Bellingham (Smith 2002). Currently, the passage of salmon and steelhead over the Middle Fork Diversion Dam is being evaluated by comanagers.

The Skagit River Basin contains two dam complexes, the Upper and Lower Baker dams on the Baker River, and the Ross, Diablo, and Gorge dams on the Skagit River. Lower Baker Dam was completed in 1927 at RKm 1.8 of the Baker River. Passage above the dams is accomplished through a trap and haul program and downstream passage is accomplished via a smolt collection facility at Upper Baker Dam (known as the "gulper"). Passage efficiency is higher for larger (yearling) smolts (e.g., coho and sockeye salmon and steelhead) that migrate near the surface than for subyearling smolts (Chinook, chum, and pink salmon). The other dam complex, incorporating the Ross, Diablo, and Gorge dams, limits access at RKm 155.3 on the Upper Skagit River. Surveys undertaken during the 1920s, prior to the construction of the first of the dams, report that anadromous fish were not present at or above the proposed location of the dams (Smith and Royal 1924). Similarly, the Seattle City Light diversion dam on the South Fork Tolt River in the Snohomish River basin is located above the limit of anadromous migration (an impassable waterfall is located at RKm 12.9). While these dams do not limit the habitat accessibility, they can affect downstream anadromous population through changes in flow, or by blocking downstream recruitment of gravel and large woody debris.

Landsburg Dam (RKm 35.1) on the Cedar River has blocked anadromous access to approximately 27.4 Km of mainstem habitat since 1900. Preliminary studies are currently underway to provide passage for steelhead and other salmonids above the dam. Plans are also being studied for restoring passage to the upper Green River. In 1913, the Tacoma Water Headworks Diversion Dam eliminated access to 47.9 Km of mainstem habitat. The construction of Howard Hanson Dam (RKm 98.1) above the Diversion Dam in 1962 blocked access to several kilometers of mainstem and tributary habitat (Kerwin and Nelson 2000). It is thought that a summer run of steelhead historically existed in the Green River, but that the run was extirpated following loss to access to headwater spawning areas following the construction of the Diversion Dam.

The Buckley Diversion Dam (RKm 39.1, 1911) and the Mud Mountain Dam (RKm 47.6, 1942) impede upstream passage on the White River. Returning adults are collected at a trap associated with the Buckley Diversion Dam and trucked around both dams. Downstream smolt passage occurs through the dams rather than through a trap and haul system. In addition to upstream and downstream migration effects on salmonids, flow diversion and ramping rates can result in dewatered redds, fish strandings, delayed migration, and degraded water conditions. In the Puyallup River Basin, the Electron Dam (RKm 67.3) has blocked upstream passage for over 90 years. The construction of a fish ladder in 2000 has provided access over 16 Km of mainstem habitat. Adult and juvenile fish passge studies are currently underway.

In the Nisqually River Basin, the LaGrande Dam (RKm 63.5. 1945) and Alder Dam (RKm 66, 1944) block upstream migration. There are currently no plans to provide passage around these dams.

The two Cushman dams, Dam No. 1 (RKm 31.5, 1926) and Dam No. 2 (RKm 27.8, 1930) eliminated anadromous access to much of the North Fork Skokomish River. Anecdotal evidence suggests that steelhead utilized much of the North Fork, although it is not clear whether these were winter- or summer-run steelhead. Additionally, the diversion of flow from the North Fork to the powerhouse has reduced the overall flow of the Skokomish River by 40% (USFS 1995).

In the Elwha River Basin, two dams, the Elwha Dam (RKm 7.9, 1911) and the Glines Canyon Dam (RKm 21.6, 1927) block access to over 100 Km of historical mainstem and tributary habitat. Both dams are scheduled to be removed beginning in 2008.

Artificial Propagation

Artificial propagation is important to consider in ESA evaluations of anadromous Pacific steelhead for several reasons. First, although natural fish are the focus of ESU determinations, both positive and negative effects of artificial propagation on natural populations must also be evaluated (NMFS 2005). For example, stock transfers might change the genetic or life-history characteristics of a natural population in such a way that the population might seem either less or more distinctive than it was historically. Artificial propagation can also alter life-history characteristics such as smolt age and migration and spawn timing. In contrast to other risks, the effects of artificial propagation can be cumulative. Domestication and genetic introgression represent processes with effects that increase over time, even if applied at the same intensity over time.

Second, artificial propagation poses a number of risks to natural populations that may affect their risk of extinction or endangerment. In contrast to most other types of risk for salmon populations, those arising from artificial propagation are often not reflected in traditional indices of population abundance. For example, to the extent that habitat degradation, overharvest, or hydropower development have contributed to a population's decline, these factors will already be reflected in population abundance data and accounted for in the risk analysis. The same is not true of artificial propagation. Hatchery production may mask declines in natural populations that will be missed if only raw population abundance data are considered. Therefore, a true assessment of the viability of natural populations cannot be attained without information about the contribution of naturally spawning hatchery fish. Furthermore, even if such data are available, they will not in themselves provide direct information about possibly deleterious effects of fish culture. Such an evaluation requires consideration of the genetic and demographic risks of artificial propagation for natural populations. The sections on artificial propagation in this report are intended to address these concerns.

In its review of Puget Sound artificial programs, the BRT identified only two hatchery stocks that genetically represent native local populations (Hamma Hamma and Green River natural winter-run). The remaining programs, which account for the vast preponderance of production, are either out-of-ESU derived stocks or were within-ESU stocks that were substantially diverged from local populations. Intentional and inadvertent selection on life history in Chambers Creek winter-run steelhead has resulted in dramatic changes in important life-history characteristics (Crawford 1979, Busby et al. 1996). These changes have resulted in a domesticated strain with a highly modified average run and spawn timing. Such changes were generally considered by the BRT to have a detrimental effect on fitness in the wild. This view was substantiated by comments made by WDFW that hatchery-derived winter-run steelhead do not contribute to natural production due to poor spawning success (see also Berejikian and Ford 2004).

Genetic analyses by Phelps et al. (1997) indicated that in some naturally spawning populations in larger river basins there is little if any detectable influence from the years of Chambers Creek hatchery winter-run steelhead introductions, a result that suggests reproductive isolation of and poor spawning success by hatchery-origin fish. There was, however, some evidence for introgression by hatchery releases into winter-run steelhead populations in tributaries to the Strait of Juan de Fuca, although this may have been due to the relatively small size of the naturally-spawning populations relative to the hatchery introductions. Efforts by WDFW to limit interactions between hatchery and wild fish through the use of early returning Chambers Creek winter-run steelhead may have reduced the probability of interbreeding through temporal separation; however, many members of the BRT considered that the fitness consequences of hatchery-wild crosses that do occur may be highly detrimental.

The BRT was also concerned that WDFW has focused on collecting abundance information after the 15 March date to delineate hatchery and native winter-run spawning. This approach does not appear to always provide an accurate estimate of the contribution of hatchery-origin fish to natural production and could bias productivity estimates. In the absence of definitive information regarding the contribution of artificial production programs to natural production in ESU, there was some uncertainty in the risk evaluation. In general, given the genetic and life-history relationships between hatchery programs derived from Chambers Creek Hatchery and Skamania Hatchery and the naturally-spawning populations the BRT concluded that these effects would be detrimental, and potentially substantially so. The two hatchery programs that were derived recently from their naturally spawning population counterparts were relatively small and had not been in operation long enough to adequately assess what contribution they made to the ESU. Even if these contributions are positive, however, the BRT concluded that these two small programs in themselves were unlikely to have a significant effect on ESU viability.

ESU Risk Assessment

Salmonid ESUs are typically metapopulations; that is, they are usually composed of multiple populations with some degree of interconnection, at least over evolutionary time periods. These multiple populations make the assessment of extinction risk difficult. The approach to this problem that NMFS adopted for recovery planning is outlined in the Viable Salmonid Populations (VSP) report (McElhany et al. 2000). In this approach, risk assessment is addressed at two levels: first at the population level, then at the overall ESU level. The BRT's risk assessment for the Puget Sound steelhead ESU incorporated VSP criteria.

The BRT assessed risk in individual populations according to the four VSP criteria: abundance, growth rate/productivity, spatial structure, and diversity. It then summarized the condition of individual populations on the ESU level and considered larger-scale issues in evaluating the status of the ESU as a whole. These larger-scale issues included total number of viable populations, geographic distribution of these populations (to ensure inclusion of major life-history types and to buffer the effects of regional catastrophes), and connectivity among these populations (to ensure appropriate levels of gene flow and recolonization potential in case of local extirpations). McElhany et al. (2000) described these considerations.

The BRT used the revised risk matrix for the overall ESU evaluation (Good et al. 2005; Table 4). This matrix integrates the four major VSP criteria (abundance, productivity, spatial structure, and diversity) directly into the risk assessment process. The BRT reviewed relevant biological information, including recent data provided by Washington State and Tribal comanagers on abundance and productivity in Puget Sound *O. mykiss*. Additional information on the production of hatchery fish and occurrence of resident fish in the Puget Sound ESU was also reviewed by the BRT. Following a discussion of each of these issues, each BRT member assigned a risk score (see below) to each of the four VSP criteria. The BRT tallied and reviewed the scores before making its overall risk assessment. Although this process helps to integrate and quantify a large amount of diverse information, there is no simple way to translate the risk matrix scores directly into an assessment of overall risk. For example, simply averaging the values of the various risk factors would not be appropriate: an ESU at high risk for low abundance would be at high risk even if there were no other risk factors.

Risk Assessment Methods

We adopted the methods described by Good et al. (2005) to evaluate data that affect the four VSP parameters in the Puget Sound steelhead ESU; these methods are described briefly below. Data on abundance, the fraction of hatchery-origin spawners, harvest, age structure, and hatchery releases were provided to the BRT by state and tribal comanagers. Data on adult returns were obtained from a variety of sources, including time series of freshwater spawner surveys, redd counts, catch data, and juvenile density estimates. Time series were assembled and analyzed for each population that had sufficient data.

Data were reviewed for accuracy and completeness by state and tribal comanagers. Population-level estimates of the fraction of hatchery-origin spawners were obtained from comanager data on proportions of adipose fin-clipped fish (i.e., hatchery fish). Estimates of harvest were provided for most stocks.

Recent Abundance

Recent abundance of natural spawners is reported as the geometric mean (and range) of the most recent data to be consistent with previous coastwide status reviews of these species. Geometric means were calculated to represent the recent abundance of natural spawners for each population or quasi-population within an ESU. Geometric means were calculated for the most recent five years; these time frames were selected to correspond with modal age at maturity for each species. Zero values in the data set were replaced with a value of 1, and missing data values within a multiple-year range were excluded from geometric mean calculations. The geometric mean is the *n*th root of the product of the *n* data:

$$\overline{X}_G = \sqrt[n]{N_1 N_2 N_3 \ldots N_n} \,,$$

where N_t is the abundance of natural spawners in year t. Arithmetic means (and ranges) were also calculated for the most recent abundance data:

$$\overline{X}_A = \frac{\sum N_i}{n} \,,$$

where N_t is the abundance of natural spawners in year t.

Trends in Abundance

Short-term and long-term trends were calculated from time series of the total number of adult spawners. Short-term trends were calculated using data from 1995 to the most recent year (2004). Long-term trends were calculated using all data in a time series.
Trend was calculated as the slope of the regression of the number of natural spawners (log-transformed) over the time series; to mediate for zero values, 1 was added to natural spawners before transforming the data. Trend was reported in the original units as exponentiated slope, such that a value > 1 indicates a population trending upward, and a value < 1 indicates a population trending downward. The regression was calculated as:

$$\ln(N+1) = \beta_0 + \beta_1 X + \varepsilon ,$$

where N is the natural spawner abundance, β_0 is the intercept, β_1 is the slope of the equation, and ε is the random error term.

Confidence intervals (95%) for the slope, in their original units of abundance, were calculated as

$$\exp(\ln(b_1) - t_{0.05(2),df} s_{b_1}) \le \beta_1 \le \exp(\ln(b_1) + t_{0.05(2),df} s_{b_1}) ,$$

where b_1 is the estimate of the true slope, β_1, $t_{0.05(2),\, df}$ is the two-sided t-value for a confidence level of 0.95, df is equal to $n - 2$, n is the number of data points in the time series, and s_{b1} is the standard error of the estimate of the slope, b_1.

Population Growth Rate

In addition to analyses of trends in natural spawners, the median short-term population growth rate (λ) of natural-origin spawners was calculated where possible as a measure for comparative risk analysis. Lambda more accurately reflects the biology of steelhead, as it incorporates overlapping generations and calculates running sums of cohorts. It is an essential parameter in viability assessment, as most population extinctions are the result of steady declines, λ < 1. It has been developed for data sets with high sampling error and age-structure cycles (Holmes 2001). These methods have been extensively tested using simulations for both threatened and endangered populations as well as for stocks widely believed to be at low risk (Holmes 2004), and cross-validated with time series data (Holmes and Fagan 2002).

Where possible, the λ of natural-origin spawners was calculated on the basis of natural production alone. Where it was not possible to separate hatchery and natural production, we computed λ based on the mixture of hatchery and natural spawners. A multi-step process based on methods developed by Holmes (2001), Holmes and Fagan (2002) and described in McClure et al. (2003) was used to calculate estimates for λ, its 95% confidence intervals, and its probability of decline [P(λ < 1)]. The first step was calculating 4-year running sums for natural-origin spawners as

$$R_t = \sum_{i=1}^{4} N_{t-i+1} ,$$

where N_t is the number of natural-origin spawners in year *t.* A 4-year running sum window was used for all species, as analysis by McClure et al. (in press) indicates that this is an appropriate window for a diverse range of species life histories.

Next, an estimate of μ, the rate at which the median of *R.* changes over time (Holmes 2001), was calculated as

$$\hat{\mu} = mean\left(\ln\left(\frac{R_{t+1}}{R_t}\right)\right),$$

the mean of the natural log-transformed running sums of natural-origin spawners. The point estimate for λ was then calculated as the median annual population growth rate,

$$\hat{\lambda} = e^{\hat{\mu}}.$$

Confidence intervals (95%) were calculated for $\hat{\lambda}$ to provide a measure of the uncertainty associated with the growth rate point estimate. First, an estimate of variability for each population was determined by calculating an estimate for σ^2_{pop} using the slope method (Holmes 2001). The slope method formula is

$$\hat{\sigma}^2_{pop} = \text{slope of var}\left(\ln\left(\frac{R_{t+\tau}}{R_t}\right)\right) \text{vs.}\, \tau.,$$

where τ is a temporal lag in the time series of running sums.

Individual population variance estimates were highly uncertain, so a more robust variance estimate, σ^2_{avg}, was obtained by averaging the σ^2_{pop} estimates from all the populations in an ESU. This average variance estimate was then applied as the variance for every population in an ESU. The degrees of freedom associated with the average variance estimate are obtained by summing the degrees of freedom for each of the individual population variance estimates. The degrees of freedom for the individual population estimates were determined using the method of Holmes and Fagan (2002), which identifies the adjusted degrees of freedom associated with slope method variance estimates. The calculation for the adjusted degrees of freedom is

$$df = 0.212n - 1.215,$$

where *n* is the length of the time series. Using the average variance estimate and the summed degrees of freedom, the 95% confidence intervals for λ were calculated as

$$\exp\left(\hat{\mu} \pm t_{.05(2),df}\sqrt{\hat{\sigma}_{slp}^{\;2}/(n-4)}\right).$$

Recruitment

Recruits, or spawners in the next generation, from a given broodyear were calculated as

$$C_t = \sum_{i=1}^{MaxAge} N_{t+i} A(i)_{t+i} \;,$$

where C_t is the number of recruits from broodyear t, N_t is the number of natural-origin spawners in year t, and $A(i)_t$ is the fraction of age i spawners in year t. The estimate of preharvest recruits is similarly

$$C(preHarvest)_t = \sum_{i=1}^{MaxAge} P_{t+i} A(i)_{t+i} ,$$

where $C(preHarvest)_t$ is the number of preharvest recruits in year t, P_t is the number of natural-origin spawners that would have returned in year t if there had not been a harvest, and $A(i)_t$ is the fraction of age i spawners in year t had there not been a harvest. (Because P_t is in terms of the number of fish that would have appeared on the spawning grounds had there not been a harvest, it can be quite difficult to estimate, thus simplifying assumptions are often made).

Population Viability Analysis

A variety of quantitative approaches to population viability analysis (PVA) have been used with Pacific salmonids. However, because no consensus has emerged on how best to model population viability in steelhead and because the available data were insufficient to conduct a robust PVA, we did not conduct one for this report.

Resident Fish Considerations

As mentioned above, *O. mykiss* exhibits varying degrees of anadromy, even in coastal populations. Nonanadromous forms are usually called rainbow trout. Although the anadromous and nonanadromous forms have long been taxonomically classified within the same species, in any given area the exact relationship between the forms is not well understood. In coastal populations, it may be less common for the two forms to co-occur; they are frequently separated by a natural or man-made migration barrier. As part of its review, the BRT made a concerted to seek biological information for resident populations of *O. mykiss* in the Puget Sound ESU.

The BRT had to consider in general terms how to conduct an overall risk assessment for an ESU that includes both resident and anadromous populations, particularly when the resident individuals may outnumber the anadromous ones but their biological relationship is unclear or unknown. Some guidance is found in Waples (1991), which outlined the scientific basis for the NMFS ESU policy. That paper suggested that an ESU that contains both forms could be listed based on a threat to only one of the life-history traits "if the trait were genetically based and loss of the trait would compromise the 'distinctiveness' of the population" (p. 16). That is, if anadromy were considered important in defining the distinctiveness of the ESU, loss of that trait would be a serious ESA concern. In discussing this issue, the NMFS ESU policy (NMFS 1991) affirmed the importance of considering the genetic basis of life-history traits such as anadromy and recognized the relevance of a question posed by one commenter: "What is the likelihood of the nonanadromous form giving rise to the anadromous form after the latter has gone locally extinct?"

The BRT discussed another important consideration—the role anadromous populations play in providing connectivity and linkages among different spawning populations within the ESU. An ESU in which all anadromous populations are lost and the remaining resident populations are fragmented and isolated would have a very different future evolutionary trajectory than one in which all populations remain linked genetically and ecologically by anadromous forms. Furthermore, in the geographic area utilized by anadromous (but not resident) fish may represent a "significant portion of the range" of the ESA species, especially if the area encompassed by the marine migration is considered.

Despite concerted efforts to collect and synthesize available information on resident forms of *O. mykiss*, existing data are very sparse, particularly regarding interactions between resident and anadromous forms. The 2003 coastwide BRT struggled with the complexity of the relationship between resident and anadromous forms, given this paucity of key information. To focus the issue, this BRT considered a hypothetical scenario that has varying degrees of relevance to individual steelhead ESUs. In this scenario, a once-abundant and widespread anadromous life history is extinct, or nearly so, but relatively healthy native populations of resident fish remain in many geographic areas. The question the BRT considered was: Under what circumstances would one conclude that such an ESU was not in danger of extinction or likely to become endangered? The BRT identified the required conditions as follows:

> The resident forms are capable of maintaining connectivity among populations to the extent that the ESU's historical evolutionary processes are not seriously disrupted.
>
> The anadromous life history is not permanently lost from the ESU but can be regenerated from the resident forms.

Regarding the first criterion, although some resident salmonid forms are known to migrate considerable distances in freshwater, extensive river migrations have not been demonstrated to be an important behavior for resident *O. mykiss*, except in rather specialized circumstances (e.g., forms that migrate from a stream to a large lake or reservoir as a surrogate for the ocean). Therefore, the BRT felt that loss of the anadromous form would, in most cases, substantially change the character and future evolutionary potential of the Puget Sound steelhead ESU. Regarding the second criterion, it is well established that resident forms of *O. mykiss* can occasionally produce anadromous migrants, and vice versa (Mullan et al. 1992, Zimmerman and Reeves 2000, Kostow 2003, Thrower et al. 2004). However, available information indicates that these occurrences are relatively rare, and there is even less empirical evidence that, once lost, a self-sustaining anadromous run can be regenerated from a resident salmonid population. Although regeneration is likely to have occurred during the evolutionary history of *O. mykiss,* the BRT found no reason to believe that such an event would occur with any frequency or within a specified time period. This would be particularly true if the conditions that promote and support the anadromous life history continue to deteriorate. In this case, the expectation would be that natural selection would gradually eliminate the migratory or anadromous trait from the population, as individuals inheriting a tendency for anadromy migrate out of the population but do not survive to return as adults and pass on their genes to subsequent generations (but see also Thrower et al. 2004).

Given the above considerations, the Puget Sound steelhead BRT focused primarily on information for anadromous populations in the risk assessment for the Puget Sound steelhead ESU. This was particularly true with respect to Category 3 resident fish populations, most of which are of uncertain ESU status.

Risk Assessment Summary

Recent Abundance

Although populations of steelhead in the Puget Sound ESU include both summer- and winter-run life-history types, the ESU is composed primarily of winter-run populations. WDFW (SaSI 2002) has identified 53 populations of steelhead in this ESU, of which 37 are winter-run. However, no abundance estimates exist for most of the summer-run populations; all appear to be small, most averaging less than 200 spawners annually. Summer-run populations are distributed throughout the ESU but are concentrated in northern Puget Sound and Hood Canal; only the Elwha River and Canyon Creek support summer-run steelhead in the rest of the ESU. The existing Elwha River summer run is largely or wholly descended from introduced Skamania Hatchery summer-run steelhead, while historical summer runs in the Green River and Elwha River are thought to have been extirpated early in the 1900s.

Steelhead are most abundant in the ESU in northern Puget Sound, with winter-run steelhead in the Skagit and Snohomish rivers supporting the two largest populations (Table 5 and Figure 6). In recent years, the Skagit and Snohomish river winter-run populations have been three to five times larger than the other populations in the ESU, and average approximately 3,000 (Snohomish) and 5,000 (Skagit) total adult spawners annually. Populations in Hood Canal and along the Strait of Juan de Fuca are generally small, averaging less than 100 spawners annually. The geometric means of most populations have declined in the last five years; recent means for many populations are 50-80% of the corresponding long-term means (Table 5). Exceptions to this trend include winter-run populations in the Samish River (northern Puget Sound) and the Hamma Hamma River (Hood Canal), both of which appear to be growing rapidly (Figures 6 and 8). In the case of the Samish River, the increasing trend in abundance is difficult to explain. The consistent increase in natural abundance since 1998 may reflect an influence of hatchery spawners. HSRG (2002, 2003, 2004) noted that hatchery steelhead produced in the Whatcom Creek Hatchery had run timing similar to wild steelhead in the Samish. Thus, because run timing is likely to be heritable, recent abundance estimates in the Samish River may include some later returning hatchery fish, or naturally produced progeny of hatchery fish that returned with wild fish. Recent abundance in the Hamma Hamma River reflects the effect of a hatchery supplementation program operating with local broodstock since 2001.

Since its 1992 SASSI report, WDFW (SaSI 2002) observed a general downgrade in the status of steelhead populations in this ESU. Over this period, the number of populations considered to be “healthy” declined from 14 (26% of all populations in the ESU) to 5 (9%), and the number of populations of “depressed” status increased from 14 (26%) to 19 (35%). One population (1%) remained “critical,” but the number of populations of unknown status increased from 24 (45%) to 27 (50%).

According to WDFW, naturally produced adult steelhead make up a substantial fraction of recent escapements in most steelhead populations (Table 5), despite reduced harvest of hatchery steelhead in recent years and in the presence of continued releases of hatchery steelhead in many systems.

Table 5. Geometric mean estimates of escapement for Puget Sound steelhead. For each population, estimates are provided for both the entire dataset (all yr, ca. 1980-2004 for most populations) and for the most recent five years (5 yr, 2000-2004). Estimates are based on hatchery and natural spawners (H+N, left columns) or on only natural spawners (N, right columns) (note that hatchery fish are not considered to be part of the Puget Sound steelhead ESU). NPS, Northern Puget Sound; SPS, Southern Puget Sound; HC, Hood Canal; SJF, Strait of Juan de Fuca. SSH, summer-run steelhead; WSH, winter-run steelhead. N/A, data not available.

Region	Run type	Population	H+N, all yr	H+N, 5 yr	N, all yr	N, 5 yr
NPS	SSH	Canyon	N/A	N/A	N/A	N/A
NPS	SSH	Skagit	N/A	N/A	N/A	N/A
NPS	SSH	Snohomish	N/A	N/A	N/A	N/A
NPS	SSH	Stillaguamish	N/A	N/A	N/A	N/A
NPS	WSH	Canyon	N/A	N/A	N/A	N/A
NPS	WSH	Dakota	N/A	N/A	N/A	N/A
NPS	WSH	Nooksack	N/A	N/A	N/A	N/A
NPS	WSH	Samish	684.2	852.2	500.8	852.2
NPS	WSH	Skagit	7720.4	5608.5	6993.9	5418.8
NPS	WSH	Snohomish	5283.0	3230.1	5283.0	3230.1
NPS	WSH	Stillaguamish	1027.7	550.2	1027.7	550.2
NPS	SSH	Tolt	129.2	119.0	129.2	119.0
SPS	SSH	Green	N/A	N/A	N/A	N/A
SPS	WSH	Cedar	137.9	36.8	137.9	36.8
SPS	WSH	Green	2050.6	1625.5	1802.1	1619.7
SPS	WSH	Lk. Washington	247.1	36.8	308.0	36.8
SPS	WSH	Nisqually	1136.7	392.4	1115.9	392.4
SPS	WSH	Puyallup	1881.5	1001.0	1714.4	907.3
HC	WSH	Dewatto	27.0	24.7	24.0	24.7
HC	WSH	Dosewallips	70.6	76.7	70.6	76.7
HC	WSH	Duckabush	16.6	17.7	16.6	17.7
HC	WSH	Hamma Hamma	29.6	51.9	29.6	51.9
HC	WSH	Quilcene	16.8	15.1	16.8	15.1
HC	WSH	Skokomish	439.3	202.8	439.3	202.8
HC	WSH	Tahuya	131.8	117.0	113.9	117.0
HC	WSH	Union	57.1	55.3	55.0	55.3
SJF	SSH	Elwha	N/A	N/A	N/A	N/A
SJF	WSH	Dungeness	311.2	173.8	311.2	173.8
SJF	WSH	Elwha	459.5	210.0	N/A	N/A
SJF	WSH	McDonald	N/A	N/A	149.8	96.1
SJF	WSH	Morse	132.6	103.0	105.8	103.0

Figure 6. Trends in natural escapement and run size for steelhead in the northern Puget Sound region of the Puget Sound ESU. Escapements are represented by shaded circles and solid lines (–○–); run sizes are represented by open triangles and dotted lines (··Δ··). The curved lines indicate 95% confidence bounds of linear regressions of abundance on year (solid, escapement trends; dotted, run size trends). All estimates are for naturally produced fish. Note that the Tolt population is a summer-run population; all others are winter-run populations. SSH, summer-run steelhead; WSH, winter-run steelhead.

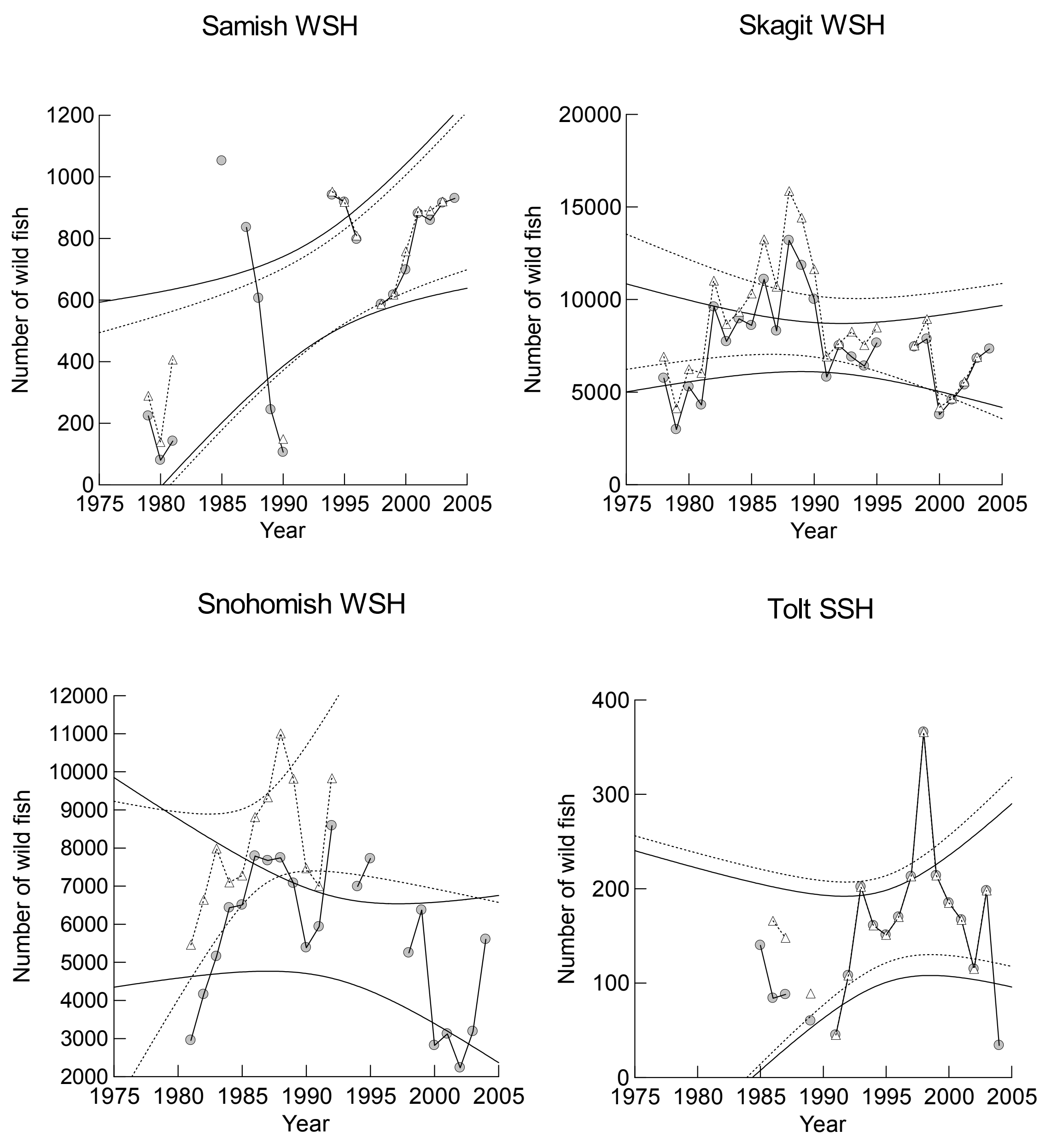
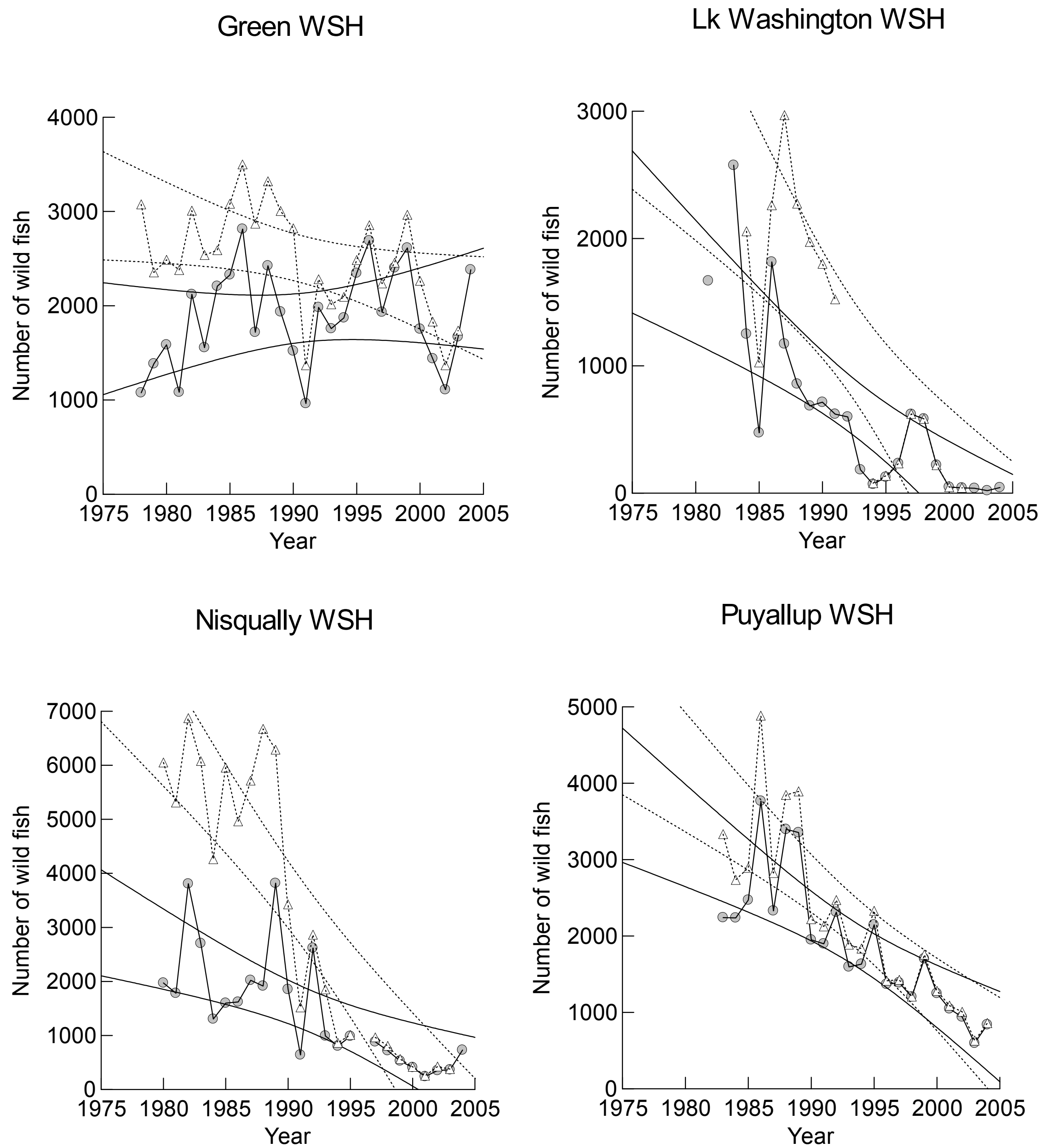


Figure 7. Trends in escapement and run size for steelhead in the southern Puget Sound region of the Puget Sound ESU. Escapements are represented by shaded circles and solid lines (–○–); run sizes are represented by open triangles and dotted lines (··Δ··). The curved lines indicate 95% confidence bounds of linear regressions of abundance on year (solid, escapement trends; dotted, run size trends). All estimates are for naturally produced fish, except for the Cedar population, which includes hatchery as well as natural fish. WSH, winter-run steelhead.



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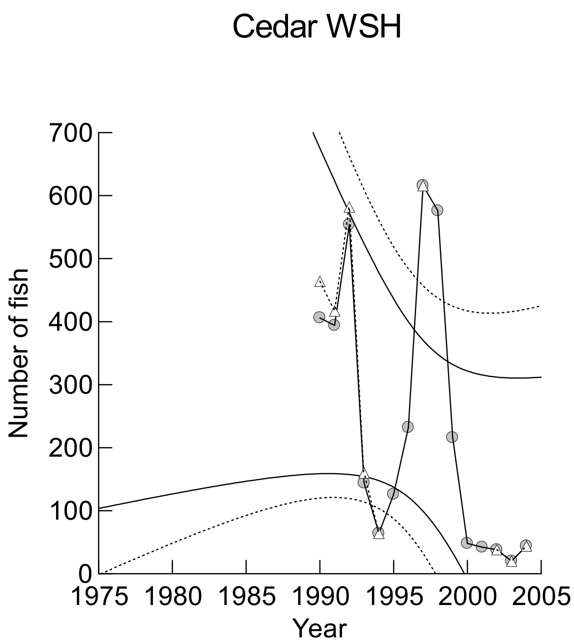
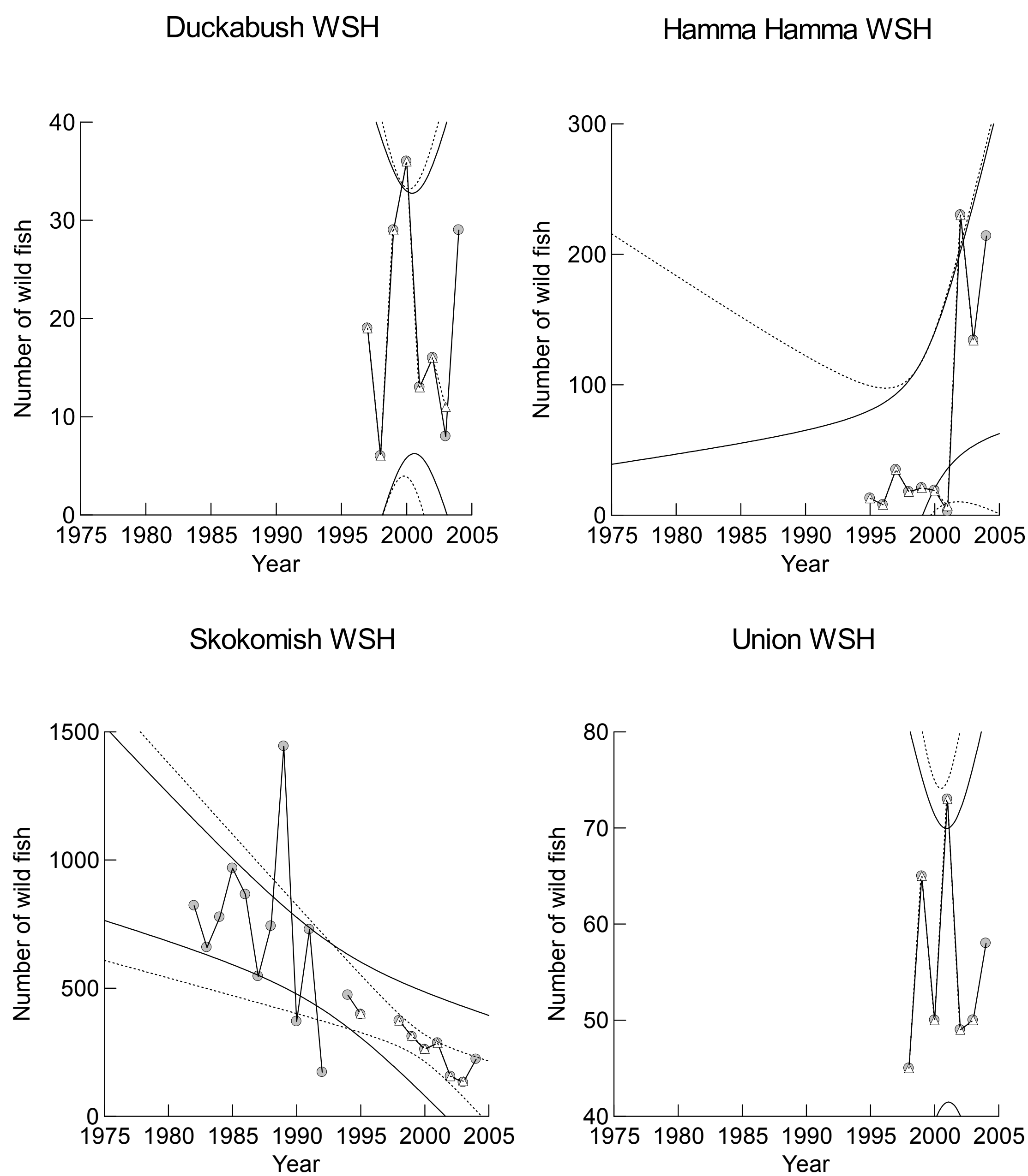


Figure 8. Trends in natural escapement and run size for steelhead in the Hood Canal region of the Puget Sound ESU. Escapements are represented by shaded circles and solid lines (–○–); run sizes are represented by open triangles and dotted lines (··Δ··). The curved lines indicate 95% confidence bounds of linear regressions of abundance on year (solid, escapement trends; dotted, run size trends). All estimates are for naturally produced fish, except for the Hamma Hamma population, which has employed a hatchery supplementation program involving local broodstock since 2001. WSH, winter-run steelhead.



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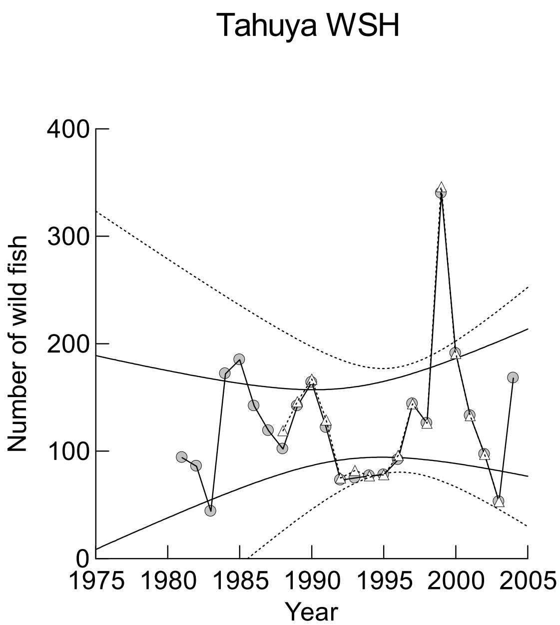


Trends in Abundance

The BRT evaluated trends in abundance of natural steelhead both over the entire data sets and over the most recent decade. Trends were measured for total run size to the river (catch and escapement) as well as escapement, as trend in run size better reflects changes in productivity. Most populations showed significantly declining trends in natural escapement, especially in southern Puget Sound (Cedar, Lake Washington, Nisqually, and Puyallup winter-run populations), but also in some populations in northern Puget Sound (Stillaguamish winter-run), Hood Canal (Skokomish winter-run), and along the Strait of Juan de Fuca (Dungeness winter-run) (Table 6 and Figures 7-9). Positive trends were observed in the Samish winter-run (northern Puget Sound) and the Hamma Hamma winter-run (Hood Canal) (Figures 6 and 8). The increasing trend on the Hamma Hamma River appears to be due to a captive rearing program, however, rather than to natural escapement (see below).

Several of the negative trends in escapement of naturally produced fish result from peaks in natural escapement in the early 1980s. Trends over the most recent decade were also strongly negative for several populations, however, especially in southern Puget Sound (Green, Lake Washington, Nisqually, and Puyallup winter-run), Hood Canal (Skokomish winter-run), and along the Strait of Juan de Fuca (Dungeness winter-run) (Table 6 and Figures 7-9). Recent positive trends are evident in natural escapement for the Samish and Hamma Hamma winter-run populations, and also in the Snohomish winter-run (Table 6 and Figures 6 and 8).

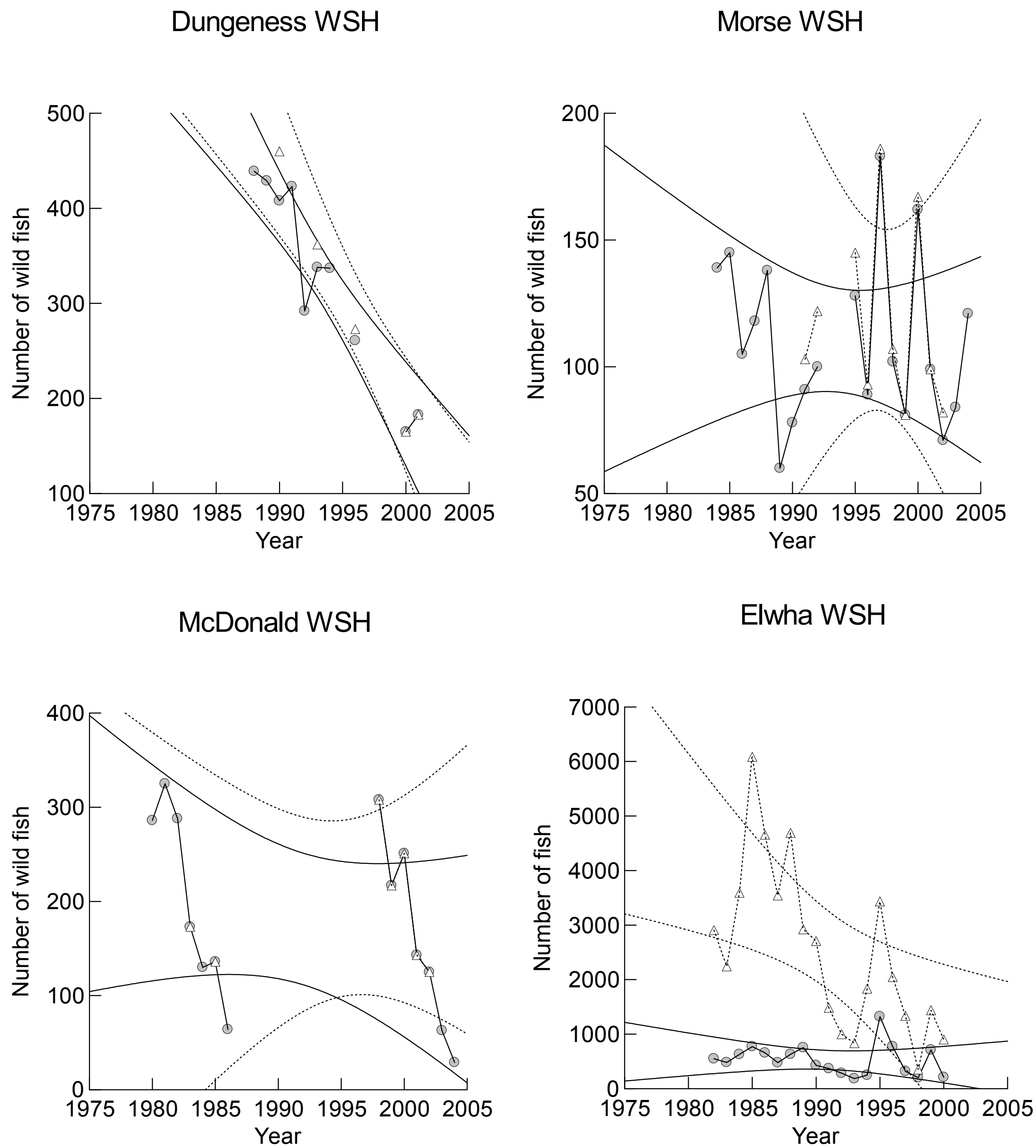
Run sizes of naturally produced steelhead generally show less consistent temporal trends than escapement of naturally produced steelhead because of management for numerical escapement goals for steelhead in the ESU (Figures 6-9). Nevertheless, marked declines in natural run size are evident in all areas of the ESU, a pattern that reflects widespread reduced productivity of natural steelhead. Declines over the entire series are observed in northern Puget Sound (Stillaguamish winter-run), southern Puget Sound (Cedar, Lake Washington, and Puyallup winter-run), Hood Canal (Skokomish winter-run), and along the Strait of Juan de Fuca (McDonald winter-run) (Table 6 and Figures 7-9). More recently, even sharper declines are observed in southern Puget Sound (Green and Nisqually winter-run) and in Hood Canal (Skokomish winter-run); significant declines persist in others, including southern Puget Sound (Puyallup winter-run) and along the Strait of Juan de Fuca (McDonald winter-run) (Table 6 and Figures 7 and 9). No population, with the exception of the small Hamma Hamma winter-run population, is showing evidence of improved productivity in more recent years, as measured by natural run size. During the BRT's discussion, one member familiar with the Hamma Hamma population indicated that the recent increase in the Hamma Hamma River's run size was due to the inclusion of fish produced from a hatchery supplementation program in the abundance estimates.

Throughout the ESU, natural steelhead production has shown at best a weak response to reduced harvest since the mid 1990s. The declines in natural production and productivity are most pervasive in southern Puget Sound but occur throughout much of the ESU. These trends reflect patterns primarily in winter-run steelhead, for which available data are most plentiful.

Table 6. Estimates of temporal trends in escapement (E) and total run size (R.) (transformed by natural logarithms) for Puget Sound steelhead. Estimates are the slopes of the regressions of natural log (spawners or run size) on year. For each population, trends are provided for both the entire dataset (all yr) and for the most recent 10 years (10 yr). Estimates are based on naturally produced fish. *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$; ****, $P < 0.0001$ (all other values are not significant). NPS, Northern Puget Sound; SPS, Southern Puget Sound; HC, Hood Canal; SJF, Strait of Juan de Fuca. SSH, summer-run steelhead; WSH, winter-run steelhead. N/A, data not available.

Region	Run type	Population	E, all yr	E, 10 yr	R., all yr	R., 10 yr
NPS	SSH	Canyon	N/A	N/A	N/A	N/A
NPS	SSH	Skagit	N/A	N/A	N/A	N/A
NPS	SSH	Snohomish	N/A	N/A	N/A	N/A
NPS	SSH	Stillaguamish	N/A	N/A	N/A	N/A
NPS	WSH	Canyon	N/A	N/A	N/A	N/A
NPS	WSH	Dakota	N/A	N/A	N/A	N/A
NPS	WSH	Nooksack	N/A	N/A	N/A	N/A
NPS	WSH	Samish	+0.067**	+0.061**	+0.019	+0.014
NPS	WSH	Skagit	–0.002	–0.010	–0.021	–0.056
NPS	WSH	Snohomish	–0.019	+0.035*	–0.086	N/A
NPS	WSH	Stillaguamish	–0.065****	N/A	–0.110*	N/A
NPS	SSH	Tolt	+0.025	+0.034	–0.107	–0.021
SPS	SSH	Green	N/A	N/A	N/A	N/A
SPS	WSH	Cedar	–0.179**	N/A	–0.299*	N/A
SPS	WSH	Green	+0.008	–0.016**	–0.048	–0.069*
SPS	WSH	Lk. Washington	–0.180****	–0.215****	–0.300*	–0.274
SPS	WSH	Nisqually	–0.084****	–0.147****	–0.097	–0.159**
SPS	WSH	Puyallup	–0.062****	–0.074****	–0.103**	–0.103**
HC	WSH	Dewatto	N/A	N/A	N/A	N/A
HC	WSH	Dosewallips	N/A	N/A	N/A	N/A
HC	WSH	Duckabush	+0.017	–0.018	+0.017	–0.019
HC	WSH	Hamma Hamma	+0.291*	+0.264	+0.291*	+0.264
HC	WSH	Quilcene	–0.006	N/A	–0.006	N/A
HC	WSH	Skokomish	–0.075****	–0.136**	–0.109*	–0.136**
HC	WSH	Tahuya	+0.009	–0.002	+0.004	–0.021
HC	WSH	Union	+0.008	+0.002	+0.008	+0.002
SJF	SSH	Elwha	N/A	N/A	N/A	N/A
SJF	WSH	Dungeness	–0.076****	–0.093**	–0.083	–0.093
SJF	WSH	Elwha	N/A	N/A	N/A	N/A
SJF	WSH	McDonald	–0.031	+0.009	–0.362**	–0.221*
SJF	WSH	Morse	–0.006	–0.015	–0.030	–0.050

Figure 9. Trends in escapement and run size for steelhead in the Strait of Juan de Fuca region of the Puget Sound ESU. Escapements are represented by shaded circles and solid lines (–○–); run sizes are represented by open triangles and dotted lines (··Δ··). The curved lines indicate 95% confidence bounds of linear regressions of abundance on year (solid, escapement trends; dotted, run size trends). All estimates are for naturally produced fish, except for the Elwha population, which includes hatchery as well as natural fish (see Table 5). WSH, winter-run steelhead.



Patterns for most summer-run populations are unknown (Table 6). The trends in natural escapement and run size for summer-run steelhead are best characterized in the Tolt River population, which is showing weak increases in escapement but weak declines in run size, both over the entire data series and in more recent years (Table 6 and Figure 6).

The BRT noted that declines in productivity in Puget Sound steelhead show a remarkable similarity to those observed for steelhead in British Columbia, especially along the Strait of Georgia and eastern Vancouver Island. The declines in abundance and productivity of these Canadian populations appear to have accelerated since about 1990; the causes for the declines remain unknown but prominent candidates identified as potential causes include changes in climate (measured as changes in coastal upwelling, various ocean and atmospheric climate indices, and freshwater habitat quality), hatchery production and harvest management, and increased ultraviolet radiation (Smith and Ward 2000, Smith et al. 2000, Ward 2000, and Welch et al. 2000).

Population Growth Rate

The BRT estimated median population growth rates (λ) for several populations in the ESU, using the 4-year running sums method described above (Holmes 2001, Holmes and Fagan 2002; see also McClure et al. 2003). Actual age-structure data was available for only five winter-run populations (the Skagit, Snohomish, Stillaguamish, Nisqually, and Puyallup); for the others, an average age structure was applied based on a mean of age structures within the region or across the ESU. As expected, the estimates of λ (Table 7) are consistent with the trends in natural run size: λ is less than 1, indicating declining population growth, for nearly all populations in the ESU. Exceptions include the Tolt summer-run population in northern Puget Sound and the Dewatto and Hamma Hamma winter-run populations in Hood Canal. Of the populations showing evidence of declining recent population growth, some show only slight declines, e.g., Samish and Skagit winter-run in northern Puget Sound, and Quilcene and Tahuya winter-run in Hood Canal).

However, most other populations show more pronounced declines, and these populations are distributed across the ESU. Estimates of population growth rate are alarmingly low for several populations throughout the ESU. These populations include the Snohomish and Stillaguamish winter-run in northern Puget Sound; the Cedar, Lake Washington, and Puyallup winter-run in southern Puget Sound; Skokomish winter-run in Hood Canal; and McDonald winter-run along the Strait of Juan de Fuca. If the analyses are restricted to those populations for which natural production data could be used to compute population growth rates, the Snohomish winter-run (northern Puget Sound) and Puyallup winter-run (southern Puget Sound) populations show evidence of significantly declining growth rate (Table 7). Thus, there is evidence for declining population growth in large winter-run populations in the major production areas of northern and southern Puget Sound. Relevant data are not available for nearly all of the

Table 7. Median short-term population growth rate estimates (λ) and their 95% confidence intervals for Puget Sound steelhead. For each population, estimates are computed for the most recent 10 years of data (1995-2004). Estimates in bold are based on natural spawners alone, according to WDFW delineations of hatchery and natural fish (note that the "natural" Hamma Hamma population has included a supplementation program since 2001). NPS, Northern Puget Sound; SPS, Southern Puget Sound; HC, Hood Canal; SJF, Strait of Juan de Fuca. SSH, summer-run steelhead; WSH, winter-run steelhead. N/A, data not available.

Region	Run type	Population	λ	95% CI (λ)
NPS	SSH	Canyon	N/A	N/A
NPS	SSH	Skagit	N/A	N/A
NPS	SSH	Snohomish	N/A	N/A
NPS	SSH	Stillaguamish	N/A	N/A
NPS	WSH	Canyon	N/A	N/A
NPS	WSH	Dakota	N/A	N/A
NPS	WSH	Nooksack	N/A	N/A
NPS	WSH	Samish	0.988	0.997-0.998
NPS	WSH	Skagit	0.997	0.997-0.998
NPS	WSH	Snohomish	**0.804**	N/A
NPS	WSH	Stillaguamish	**0.885**	**0.884-0.885**
NPS	SSH	Tolt	1.018	1.017-1.018
SPS	SSH	Green	N/A	N/A
SPS	WSH	Cedar	**0.808**	**0.804-0.811**
SPS	WSH	Green	0.932	0.932-0.933
SPS	WSH	Lk. Washington	0.802	0.800-0.803
SPS	WSH	Nisqually	0.918	0.917-0.918
SPS	WSH	Puyallup	**0.882**	**0.881-0.882**
HC	WSH	Dewatto	**1.020**	**1.008-1.020**
HC	WSH	Dosewallips	N/A	N/A
HC	WSH	Duckabush	N/A	N/A
HC	WSH	Hamma Hamma	1.013	N/A
HC	WSH	Quilcene	**0.988**	N/A
HC	WSH	Skokomish	**0.865**	N/A
HC	WSH	Tahuya	0.983	0.982-0.983
HC	WSH	Union	**0.969**	N/A
SJF	SSH	Elwha	N/A	N/A
SJF	WSH	Dungeness	0.924	0.924-0.924
SJF	WSH	Elwha	0.966	0.965-0.966
SJF	WSH	McDonald	**0.732**	N/A
SJF	WSH	Morse	0.945	0.945-0.946

smaller populations, several of which show some evidence for declines as well. Similarly, relevant data are not available for virtually all summer-run populations in the ESU; the sole exception is the Tolt summer-run population, which is showing evidence of increasing productivity. Trends in marine survival were not available for any of the populations in the ESU.

Recruitment

Estimates of natural recruitment (naturally produced recruits per spawner, R/S) are highly variable among populations (Table 8). Low estimates (R/S < 1) are represented in winter-run populations across the range of the ESU: the Stillaguamish winter-run (northern Puget Sound), Puyallup winter-run (southern Puget Sound), Skokomish winter-run (Hood Canal), and Dungeness and Morse winter-run (Strait of Juan de Fuca). High estimates (R/S > 1) are also represented in winter-run populations across most of the range of the ESU: the Skagit and Snohomish winter-run (northern Puget Sound); Cedar, Green and Nisqually winter-run (southern Puget Sound); and Dewatto and Tahuya winter-run (Hood Canal). Most estimates, regardless of size, have high sampling variances (Table 8), and most time series are too short to account for autocorrelation.

Trends in R/S over time, where they are significant, generally reflect declines in natural recruitment rate. Declines in natural recruitment rate are evident in both of the largest populations in northern Puget Sound, the Skagit and Snohomish winter-run populations (Table 8). Significant declines are also evident in the Green and Puyallup winter-run populations in southern Puget Sound, and in the Skokomish winter-run population in Hood Canal. The Cedar winter-run population in southern Puget Sound shows evidence of strongly increasing recruitment, but this may be due to one or two strong cohorts in the 1990s (Figure 7).

Washington Trout's Analysis of Puget Sound Steelhead Productivity

Washington Trout submitted to the BRT an analysis of productivity in five major winter-run steelhead populations of the Puget Sound ESU (Gayeski 2005) for consideration as part of the evaluation of the listing petition. The five populations were the Nisqually, Puyallup, Snohomish, Stillaguamish, and Skagit. Washington Trout argued that these five populations represent a broad spatial array of populations in the ESU and include its two most robust steelhead populations, in the Skagit and the Snohomish rivers. Washington Trout stated that this analysis would therefore provide a conservative assessment of the recent productivity of the ESU.

Washington Trout evaluated stock-recruit data derived from natural run size and escapement data provided by WDFW, using age composition from Skagit River winter-run steelhead sampled in the late 1980s and early 1990s for analyses of the three northern-most populations (Snohomish, Stillaguamish, and Skagit), and age composition skewed toward younger fish for Puyallup and Nisqually. Washington Trout's recruitment analyses encompassed data through years 2001 for the Stillaguamish population to 2002 for the Snohomish and Nisqually, and 2003 for the Puyallup and Skagit populations.

Table 8. Means and variances of recruits per spawner, and estimates of the slope of the regression of recruits per spawner on year, for Puget Sound steelhead. Estimates are based on naturally produced spawners. Estimates in italics are computed from empirical age-structure estimates; all others assume an average age structure constructed for each region (see text). An asterisk indicates a significant ($P < 0.05$) temporal trend in recruits per spawner. NPS, Northern Puget Sound; SPS, Southern Puget Sound; HC, Hood Canal; SJF, Strait of Juan de Fuca. SSH, summer-run steelhead; WSH, winter-run steelhead. N/A, data not available.

Region	Run type	Population	Mean R./S	Variance in R./S	Slope, R./S vs yr
NPS	SSH	Canyon	N/A	N/A	N/A
NPS	SSH	Skagit	N/A	N/A	N/A
NPS	SSH	Snohomish	N/A	N/A	N/A
NPS	SSH	Stillaguamish	N/A	N/A	N/A
NPS	WSH	Canyon	N/A	N/A	N/A
NPS	WSH	Dakota	N/A	N/A	N/A
NPS	WSH	Nooksack	N/A	N/A	N/A
NPS	WSH	Samish	N/A	N/A	N/A
NPS	WSH	Skagit	*1.460*	*0.457*	*–0.148**
NPS	WSH	Snohomish	*1.294*	*0.285*	*–0.156**
NPS	WSH	Stillaguamish	*0.686*	*0.034*	*–0.054*
NPS	SSH	Tolt	N/A	N/A	N/A
SPS	SSH	Green	N/A	N/A	N/A
SPS	WSH	Cedar	2.302	6.608	+1.499*
SPS	WSH	Green	1.218	0.253	–0.127*
SPS	WSH	Lk. Washington	N/A	N/A	N/A
SPS	WSH	Nisqually	*1.327*	*0.647*	*+0.578*
SPS	WSH	Puyallup	*0.848*	*9.989*	*–0.052**
HC	WSH	Dewatto	1.945	4.725	–0.182
HC	WSH	Dosewallips	N/A	N/A	N/A
HC	WSH	Duckabush	N/A	N/A	N/A
HC	WSH	Hamma Hamma	N/A	N/A	N/A
HC	WSH	Quilcene	N/A	N/A	N/A
HC	WSH	Skokomish	0.785	0.125	–0.113*
HC	WSH	Tahuya	1.640	2.109	–0.028
HC	WSH	Union	N/A	N/A	N/A
SJF	SSH	Elwha	N/A	N/A	N/A
SJF	WSH	Dungeness	0.758	0.001	+0.030
SJF	WSH	Elwha	N/A	N/A	N/A
SJF	WSH	McDonald	N/A	N/A	N/A
SJF	WSH	Morse	0.819	0.094	+0.063

The analyses involved primarily fitting spawner-recruit data to two density-dependent stock recruit models, the Ricker and Beverton-Holt models, and examining the de-trended residuals from the fitted estimates. Washington Trout's analyses indicated a substantial declining trend in the time series of spawning and recruitment for all five populations since the late 1980s (similar to that observed in several coastal steelhead populations in southern British Columbia; Smith and Ward 2000, Smith et al. 2000, Ward 2000, Welch et al. 2000). A principal components analysis of the residuals indicated a common response in the populations.

Washington Trout concluded from their analysis that these populations of winter-run steelhead in the Puget Sound steelhead ESU have experienced a period of pronounced declines in abundance, recruitment and productivity beginning around 1989 and continuing to the present. Washington Trout also concluded that the strongly coherent pattern among these five populations indicates that these declines are ESU-wide or nearly so.

The BRT examined Washington Trout's analysis and comments on it submitted by comanagers and two scientists from the NWFSC familiar with the analytical approach. Their comments indicated that the analysis suffers from several problems, most of which stem from the use of an average age structure to estimate recruits or failing to account for errors in estimates of spawner abundance. Zabel and Levin (2002) showed that failing to account for temporal variability in age structure can bias estimates of productivity by overestimating recruitment in small cohorts and underestimating recruitment in large cohorts. R. Kope of the BRT, in an unpublished manuscript, has further explored this problem and found a similar pattern but indicated that additional biases may result in even more complex effects on the estimates. In its own analyses, the BRT could not avoid all these sources of bias but tried to minimize them by basing calculations on empirical age structure distributions that varied over time, where they were available, and identifying where this was not possible.

The BRT noted that the fit of the stock-recruit data was not evaluated quantitatively by Washington Trout, and the BRT therefore attempted to fit these data to alternative models. In general, the fit of the data to either the Ricker or the Beverton-Holt model was very poor; for each of the five populations, a simple density-independent model such as the random-walk model with trend (McElhany and Payne, in press) provided fits equally as good (analyses not shown). Nevertheless, the fits to the random-walk model were also poor.

One commenter familiar with the data pointed out that Washington Trout's analysis was also plagued by several errors in the estimates of spawners or recruits. He also observed that natural escapement estimates for most of these populations are still higher than current MSY escapement levels. Thus, the reviewer questioned the validity of the analysis and Washington Trout's conclusions drawn from it. After a review of these comments and its own analysis of productivity described above, the BRT concluded that, although these issues with the analysis taken collectively cast some doubt on the specific values of the stock-recruitment estimates and the precise magnitude of the trends in productivity, a general decline in productivity is still evident from the data. The BRT noted that this decline is consistent with the declines observed in most populations from a simple examination of temporal trend in natural run size, and is apparent to some degree even in the two largest populations, the Skagit and Snohomish (Figure 6).

Hatchery Fish

The BRT explicitly considered both the potential positive and potential negative effects of hatchery production on the ESU. Because the BRT considered virtually all hatchery steelhead produced in Puget Sound to be excluded from the Puget Sound steelhead ESU, the BRT determined that the negative effects of these programs were nearly certain to outweigh any potential positive effects. The two “in ESU “ programs, the Hamma Hamma River and the Green River, have the potential to benefit natural populations in those rivers, but neither program has yet collected sufficient data to estimate their positive (or negative) effects with any certainty. It does appear that the Hamma Hamma program has successfully increased the number of natural spawners in the population, but the success of the program will not be known until the natural offspring of the captively reared spawners return (B. Berejikian, NMFS, unpubl. data).

Risks associated with the hatchery programs in Puget Sound included potential effects of outbreeding depression resulting from the natural interbreeding of hatchery and wild fish, and adverse ecological interactions between hatchery and wild steelhead, including density-dependent effects on growth and survival. Some BRT members felt that one or both of these effects may be contributing to the declines in natural steelhead productivity, but the magnitude of the contribution could not be ascertained. In contrast to statements made in the petition (Wright 2004), WDFW indicated that the magnitude of hatchery releases had not increased in recent years and that offsite releases had been reduced (see Appendix D for release records). Several BRT members were concerned that the genetic effects of hatchery-wild interactions are cumulative and the risk to wild populations is increasing over time, even if the absolute numbers of released hatchery fish has been reduced.

Risk Assessment Conclusions

Each of the BRT members assessed the contribution to extinction risk of Puget Sound steelhead for each of the four VSP criteria: abundance, productivity, diversity, and connectivity/spatial structure. Each member used a scale of 1 (very low risk) to 5 (very high risk) (see Table 4). In evaluating the four VSP criteria, the BRT concluded that low and declining abundance and low and declining productivity were substantial risk factors for the ESU. Loss of diversity and spatial structure were judged to be moderate risk factors.

Abundance

For this VSP criterion and risk category, the BRT’s scores ranged from 3 to 4, with a modal value of 4 (mean, 3.7). These scores reflect the BRT’s assessment that the risk of declining steelhead abundance to ESU viability is high. Because of the BRT’s conclusion that virtually all hatchery summer- and winter-run steelhead populations in Puget Sound should be considered to be excluded from the ESU, the BRT focused its attention where possible on abundance of naturally produced fish. Trends in escapement and run size of natural steelhead were predominantly downward throughout much of the ESU, over both longer-term (since about 1980 for most systems) and shorter-term (since the mid 1990s) time series. For several populations, the shorter-term trends are even more sharply negative than the longer-term trends that incorporate large abundance estimates for several populations in the early 1980s.

All BRT members noted the declines in both natural escapement and natural run size for the two largest steelhead populations in the ESU (the Skagit and Snohomish river winter-run populations in northern Puget Sound), and observed that most of the other populations in the ESU are small, especially those in Hood Canal and the Strait of Juan de Fuca. These trends have occurred despite widespread reductions in direct harvest of natural steelhead in this ESU since the mid 1990s. Although steelhead populations in large systems such as the Skagit and Snohomish rivers remain relatively large (>5,000 natural adults annually), these escapements are still far below those estimated as recently as the mid 1980s, when harvest rates on natural fish were higher. Other populations in the ESU are substantially smaller, some as large as 500-1,000 adults but many exhibiting natural spawning escapements <50-100 fish annually. Summer-run population abundances were all small, and although historically they may never have been very large, there was concern regarding considerable number of populations for which no data were available.

Growth/Productivity

For this VSP criterion and risk category, the BRT's scores ranged from 3 to 5, with a modal value of 4 (mean, 4.0). These scores reflect an assessment that declining steelhead productivity poses high risk to ESU viability. The BRT noted that natural run sizes (sum of harvest and escapement) for most populations show even more marked declining trends than indicated by escapements, indicating that the substantially reduced harvest rates for natural fish since the early 1990s have not resulted in a rebound in steelhead production in Puget Sound. Estimates of the mean number of recruits per spawner are less than 1.0 in several systems, as are long-term population growth rates (λ); it is not known whether, as is the case for some British Columbia steelhead populations (Smith and Ward 2000, Ward 2000, Welch et al. 2000), there is also evidence of declining smolt-adult survival rates. For many of the Puget Sound populations the decline in adult recruits per spawner has been precipitous. Each of these measures reflects productivity declining to levels that indicate unsustainable long-term natural steelhead production if the trends continue unabated. A single exception is the relatively small Samish River winter-run steelhead population in northern Puget Sound, which is showing strong upward trends in abundance and productivity in recent years.

Diversity

For this VSP criterion and risk category, the BRT's scores ranged from 2 to 4, with a modal value of 3 (mean, 3.1). These scores reflect an assessment of that current *O. mykiss* diversity in the ESU poses moderate risk to ESU viability. Most BRT members expressed concern over the status of the summer-run populations of steelhead in the ESU. Populations of summer-run steelhead occur throughout the Puget Sound ESU but are concentrated in northern Puget Sound area, are generally small, and are characterized as isolated populations adapted to streams with distinct attributes. For the one summer-run population that has associated natural escapement and run size data, the BRT observed that the trend in abundance was predominantly negative. Indeed, several BRT members were concerned that some historical accounts (see above) discuss significant early runs of wild fish, but that these early wild spawners have apparently disappeared from several systems. The largest summer-run steelhead population in Puget Sound is in the Tolt River; this population exhibits a negative trend in natural run size and a flat trend in natural escapement. Most other populations are very small, with annual escapements below 50 fish, and some include substantial production of Skamania-stock summer-run hatchery fish (e.g., the Green River and South Fork Skykomish populations).

Although offsite releases and releases of steelhead fry and parr have largely ceased in the ESU, annual releases of hatchery steelhead smolts derived from non-local populations (Skamania summer-run steelhead) or from domesticated populations originally founded within the ESU (Chambers Creek winter-run steelhead) persist in most systems, and several of these releases are still composed of tens or hundreds of thousands of fish. This sustained hatchery management practice has elevated opportunities for interbreeding and ecological interaction between wild and hatchery fish, in spite of the apparent differences in average spawning time, and its associated adverse fitness consequences for both summer- and winter-run steelhead. As one BRT member noted, even low levels (e.g., <5%) of gene flow per year from a non-ESU hatchery stock to a naturally spawning population can have a highly significant genetic impact after several generations. High harvest rates before the mid 1990s may have removed a substantial proportion of wild summer-run and early-returning/spawning wild winter-run fish from many of these systems. Present-day high harvest rates for marked hatchery-origin fish are likely to result in continued mortality of early-returning naturally-spawning steelhead through poaching and hook-and-release mortalities. For example, although unmarked natural-origin steelhead must be released in most streams, restricted sport fishing gear that precludes baited hooks may not be required. Several BRT members were concerned that interbreeding with hatchery steelhead may be contributing to reduced productivity of natural fish. Several members also felt that the presence of these hatchery fish is likely to pose an ecological threat to wild fish through competition in estuaries and marine environments, manifested as reductions in density-dependent growth and survival at critical life-history stages.

Alternatively, some BRT members indicated that any conclusions about changes in diversity in this ESU are constrained by the lack of data on changes in age structure, or life-history or genetic diversity in Puget Sound *O. mykiss*, especially for resident fish.

Spatial Structure/Connectivity

For this VSP criterion and risk category, the BRT's scores ranged from 2 to 4, with a modal value of 3 (mean, 2.8). These scores reflect an assessment that spatial structure of *O. mykiss* in the ESU poses moderate risk to its viability. A strong majority of BRT members concluded that the ESU is likely to be at elevated risk due to reduced complexity of spatial structure of its steelhead populations and, consequently, diminishing connectivity among them. Several members felt that the declines in natural abundance for most populations, coupled with large numbers of anthropogenic barriers such as impassable culverts, sharply reduce opportunities for natural adfluvial movement and migration between steelhead aggregations in different watersheds. The sharp reduction in escapement of natural steelhead to the centrally located Lake Washington watershed in recent years was of considerable concern to most BRT members, especially given the weakening trends in abundance for populations in neighboring

Puget Sound systems. Nevertheless, most BRT members believed that resident *O. mykiss* below migration barriers in watersheds throughout the ESU may provide short-term buffers against demographic stochasticity in many of these populations. However, the lack of information on abundance and distribution on resident fish in Puget Sound watersheds makes it impossible to characterize the effectiveness of such buffers. In general, resident *O. mykiss* are considered to be a relatively minor component of these anadromous populations based on field surveys of juvenile fish in fresh water.

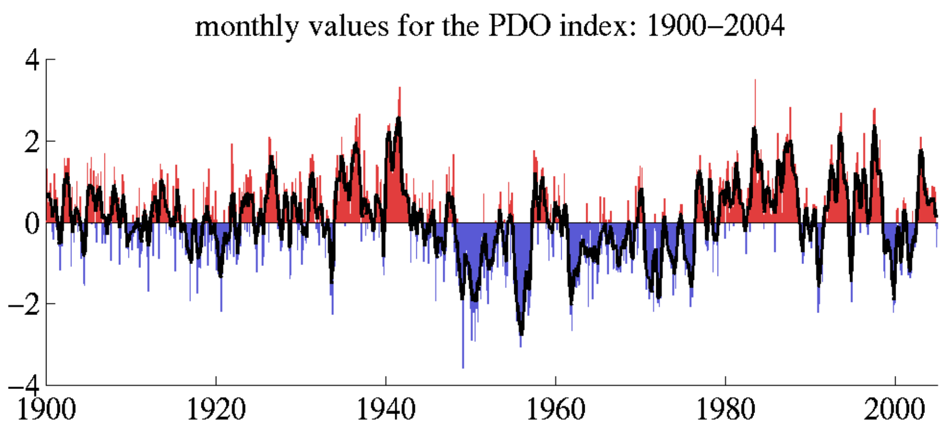
Recent Events

For recent events, the BRT's scores ranged from -- to ++, with a modal value of 0. These scores reflect an assessment that recent events, considered collectively, are likely to have a minor impact (positive or negative) on ESU viability. Reduced harvest levels and recent changes in management of natural steelhead, the recent onset of recovery efforts in Puget Sound and Hood Canal for Chinook salmon and summer-run chum salmon prompted by the listing of those ESUs, and reduced off-site plantings of hatchery steelhead were all considered as recent positive actions. However, the continued releases of out-of-ESU hatchery summer- and winter-run steelhead throughout the region, reductions in steelhead escapement goals to help support harvest opportunity in several systems (e.g., the Skagit River where WDFW has reduced natural fish escapement goals from 10,000 adults/year to 6,000 adults/year), evidence for diminishing marine survival rates, a recent increase in the Pacific Decadal Oscillation Index reflecting a general change in climate in the region toward warmer, drier conditions (Figure 10), increases in pinniped populations in Puget Sound, degradation of water quality in Hood Canal and southern Puget Sound, and continued land development and urbanization with associated impacts on freshwater habitat all are likely to increase risk to this ESU. The effects of these recent positive and negative events are difficult to estimate; most members concluded that the net effect is likely to be neutral or possibly slightly negative.

Overall Risk

The BRT's scores for overall risk category ranged from "neither at risk of extinction nor likely to become so" to "at risk of extinction," with a strong majority of members considering the ESU "likely to become at risk of extinction" in the foreseeable future. Uncertainty among the members in this conclusion was relatively low, and overall risk scores were highly consistent. Two of the 13 BRT members allocated their ten likelihood points between the "not at risk" and "likely to become at risk of extinction" risk categories at ratios of 60-70% (6-7 points) and 30-40% (3-4 points), respectively. However, all other members allocated at least 6 (and some at least 9) of their 10 points to the "likely to become at risk of extinction" category. No BRT member allocated more than 2 of their points to the "at risk of extinction" category. Thus, the conclusion that steelhead in the Puget Sound ESU are likely to become at risk of extinction in the foreseeable future—but are not currently in danger of extinction—reflected the collective scientific opinion of an overwhelming majority of the BRT.

Figure 10. Monthly values for the Pacific Decadal Oscillation (PDO) index, which is based on sea surface temperatures in the North Pacific. Values shown are deviations from the long-term mean. The negative values of the index reflect “cool” PDO regimes, while the positive values reflect “warm” PDO regimes (like those dominating from 1925-1946 and from 1977 through (at least) the mid-1990s. Major changes in northeast Pacific marine ecosystems have been correlated with phase changes in the PDO; warm eras have seen enhanced coastal ocean biological productivity in Alaska and reduced productivity off the west coast of the contiguous United States, while cold PDO eras have seen the opposite north-south pattern of marine ecosystem productivity. Source: Online at http://tao.atmos.washington.edu/pdo/.



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Appendices

Appendix A. Survey of steelhead abundance in Puget Sound streams conducted by Washington Department of Fisheries and Game during 1929 and 1930

Abundance codes (from the original source, WDFG 1932): A-large, B-medium, C-scarce, D-very scarce, X-absent

Watershed	Main River	Tributaries	Migration Distance	Survey Date	Abundance
Whatcom Co.		California Cr.	12.0	7/1/1930	X
		Dakota Cr.	10.0	6/30/1930	B
		Terrill Cr.	NA	7/1/1930	X
Nooksack River	Nooksack River		33.0		B
		Ten Mile Cr.	NA	6/11/1930	X
		Betrand Cr.	10.0	6/11/1930	D
		Fishtrap Cr.	10.0	6/10/1930	X
		Anderson Cr.	7.0	6/12/1930	X
		Weiser Cr.	NA	6/10/1930	X
		Smith Cr.	4.0	6/12/1930	X
	South Fork Nooksack River		43.0	7/10/1930	B
		Hutchinson Cr.	0.5	7/15/1930	B
		Skookum Cr.	12.0	7/2/1930	B
		Edfro Cr.	NA	7/3/1930	X
		Cavanaugh Cr.	NA	7/3/1930	X
		Howard Cr.	NA	7/15/1930	X
	North Fork Nooksack River		30.0	6/25/1930	B
		Wells Cr.	NA	6/26/1930	X
		Thompson Cr.	3.5	6/23/1930	X
		Racehorse Cr.	4.0	6/21/1930	C
		Maple Cr.	1.0	6/20/1930	D
		Kendall Cr.	6.0	6/21/1930	C
		Glacier Cr.	8.0	6/23/1930	X
		Deadhorse Cr.	NA	6/26/1930	X
		Cornell Cr.	0.8	6/24/1930	D
		Coal Cr.	0.3	6/16/1930	D
		Cascade Cr.	0.3	6/26/1930	C
		Canyon Cr.	1.0	6/20/1930	X
		Boulder Cr.	1.5	6/20/1930	X
		Bell Cr.	5.0	6/16/1930	C
		Bear Cr.	3.0	6/21/1930	X

Appendix A (continued).

Watershed	Main River	Tributaries	Migration Distance	Survey Date	Abundance
	Middle Fork Nooksack River		8.0	6/24/1930	C
		Galbraith Cr.	NA	6/24/1930	X
		Canyon Cr.	2.5	6/23/1930	B
		Clearwater Cr.	NA	6/19/1930	X
		Porter Cr.	1.5	6/19/1930	X
Skagit	Skagit River		80.0	3/29/1930	A
		Powell Cr.	5.0	5/12/1930	D
		Sorenson Cr.	4.5	5/17/1930	X
		Alder Cr.	7.0	5/23/1930	D
		Finney Cr.	9.0	7/18/1930	A
		Nookachamps Cr.	15.0	5/8/1930	D
		Boyds Cr.	NA	5/27/1930	X
		Cumberland Cr.	1.0	5/22/1930	D
		Day Cr.	12.0	5/14/1930	C
		Gilligan Cr.	2.0	5/17/1930	C
		Grandy Cr.	7.0	5/21/1930	A
		Hansen Cr.	7.0	5/15/1930	X
		Jones Cr.	7.0	5/19/1930	X
		Loretta Cr.	2.0	5/22/1930	C
		Mill Cr.	1.5	5/28/1930	D
		Muddy Cr.	6.0	5/26/1930	X
		O'Toole Cr.	0.5	5/27/1930	D
		Pressentin Cr.	1.0	5/29/1930	D
		Red Cabin Cr.	5.0	5/20/1930	X
		Slide Cr.	NA	6/5/1930	X
		Swift Cr.	1.0	6/8/1930	X
		Bacon Cr.	8.0	6/7/1930	A
		Diobsud Cr.	3.0	6/2/1930	C
		Illabat Cr.	12.0	7/5/1930	D
		Jackman Cr.	2.0	6/4/1930	X
		Rocky Cr.	NA	6/3/1930	X
	Baker River		17.50	8/25/1930	B
		Rocky Cr.	NA	8/16/1930	X
		Sulphur Cr.	NA	8/16/1930	X
		Bear Cr.	NA	8/15/1930	X
		Big Cr.	NA	8/15/1930	X
		Silver Cr.	NA	8/28/1930	X
		Morovitz Cr.	4.0	8/28/1930	C
		Thunder Cr.	NA	8/28/1930	X

Appendix A (continued).

Watershed	Main River	Tributaries	Migration Distance	Survey Date	Abundance
Skagit (cont)	Cascade River		11.0	8/8/1930	B
		Jordan Cr.	5.5	8/6/1930	A
		Marble Cr.	1.0	8/7/1930	C
		Boulder Cr.	1.0	8/8/1930	C
		Clark Cr.	1.0	8/6/1930	X
		Sibley Cr.	0.5	8/7/1930	C
	Sauk River		29.0	8/14/1930	B
		Dan Cr.	3.0	8/4/1930	B
		Backman Cr.	0.8	8/1/1930	C
		Clear Cr.	1.0	7/31/1930	C
		Goodman Cr.	1.0	8/1/1930	D
		Murphy Cr.	0.5	8/1/1930	C
		Copper Cr.	NA	8/4/1930	X
		Texas Cr.	1.0	6/8/1930	X
	Suiattle River		10.5	8/14/1930	C
		Tenas Cr.	1.5	8/13/1930	X
		Big Cr.	1.5	8/13/1930	D
Stillaguamish River	Stillaguamish River		15.0	7/1929	A
		Pilchuck Cr.	10.0	7/1929	B
		Harvey Cr.	4.0	7/1929	C
	North Fork Stillaguamish R.		40.0	7/1929	A
		Rock Cr.	2.0	7/1929	C
		Bucker Hill Cr.	NA	7/1929	X
		Deer Cr.	35.0	7/1929	A
		Grant Cr.	2.0	7/1929	C
		Boulder Cr.	6.0	7/1929	B
		French Cr.	3.0	7/1929	B
		Squire Cr.	12.0	7/1929	B
	South Fork Stillaguamish R.		15.0	7/1929	A
		Jim Cr.	6.0	7/1929	B
		Canyon Cr.	2.0	7/1929	A
Snohomish River	Snohomish River		25.0	6/1/1929	A
		Heartgravel Slough	NA	6/1/1929	X
		Slough No. 2	NA	6/2/1929	X
		Slough No. 3	NA	6/2/1929	X

Appendix A (continued).

Watershed	Main River	Tributaries	Migration Distance	Survey Date	Abundance
	Pilchuck River		25.0	6/5/1929	A
		Sexton Cr.	1.0	6/3/1929	X
		T N Cr.	5.0	6/8/1929	C
		T M Cr.	1.0	6/8/1929	D
		T L Cr.	1.0	6/9/1929	D
		T H Cr.	NA	6/10/1929	X
		West Branch	8.0	6/15/1929	C
		T O Cr.	3.0	6/16/1929	D
		T R. Cr.	4.0	6/18/1929	D
		T P Cr.	1.0	6/17/1929	D
		French Cr.	2.0	6/19/	X
	Skykomish River		40.0	6/28/1929	A
		Woods Cr.	7.0	7/2/1929	B
		WF Woods Cr.	12.0	7/3/1929	C
		Ki Cr.	1.0	6/28/1929	X
		Sultan River	8.0	6/20/1929	A
		Elwell Cr.	NA	6/24/1929	C
		Proctor Cr.	1.0	7/15/1929	C
		Wallace River	NA	6/24/1929	B
		SF Skykomish River	3.0	6/27/1929	B
		NF Skykomish River	15.0	7/1/1929	B
		Salmon Cr.	3.0	7/1/1929	C
	Snoqualmie River		48.0	8/1/1929	B
		Cherry Cr.	8.0	8/2/1929	C
		Harris Cr.	3.0	7/25/1929	C
		Griffin Cr.	2.0	7/25/1929	C
		Tark Cr.	NA	7/24/1929	X
	Tolt River		10.0	9/1/1929	A
		SF Tolt River	7.5	9/1/1929	B
		NF Tolt River	5.0	9/1/1929	A
		Lynch Cr.	2.0	9/2/1929	C
		Stossel River	2.5	9/2/1929	C
		N. Fork Cr.	5.0	9/3/1929	C
		Ragging River	9.0	9/4/1929	B

Appendix A (continued).

Watershed	Main River	Tributaries	Migration Distance	Survey Date	Abundance
Lake Washington		May Cr.	8.0	9/2/1929	X
		Mercer Slough	NA	9/3/1930	X
		Cedar River	19.0	9/2/1930	C
		Evans Cr.	5.0	9/3/1930	X
		Bear Cr.	10.0	9/3/1930	X
Duwamish River	Green River		50.0	7/28/1930	A
		Burns Cr.	2.0	7/22/1930	C
		Newaukum Cr.	14.0	7/24/1930	C
		Spaight Cr.	0.5	7/24/1930	D
		Soos Cr.	11.0	7/23/1930	A
Puyallup River	Puyallup River		50.0	7/12/1930	A
		Clear Cr. No. 1	1.0	7/21/1930	D
		Clear Cr. No. 2	0.3	7/28/1930	D
		Stoney Cr.	2.0	7/28/1930	D
		Clark Cr.	2.0	7/15/1930	D
		Deer Cr.	NA	7/15/1930	X
		McMullan Cr.	3.5	8/1/1930	C
		Mowitch Cr.	NA	7/18/1930	X
		Rushing Watter Cr.	NA	7/19/1930	X
		Carbon River	25.0	7/29/1930	A
		Voight Cr.	3.0	8/16/1930	B
		Wilkeson Cr.	7.0	8/1/1930	X
		Evans Cr.	NA	8/16/1930	X
		S. Prairie Cr.	12.0	7/31/1930	B
	White River		60.0	8/8/1930	B
		Boise Cr.	3.5	8/2/1930	D
		East Twin Cr.	NA	8/13/1930	X
		West Twin Cr.	NA	8/12/1930	X
		WF White R.	15.0	8/13/1930	C
		Goat Cr.	NA	8/9/1930	X
		Greenwater R.	9.0	8/7/1930	C
		Twenty-eight Mile Cr.	NA	8/7/1930	X
		Slippery Cr.	NA	8/14/1930	X
		Silver Cr.	NA	8/7/1930	X
		Scatter Cr.	NA	8/11/1930	X

Appendix A (continued).

Watershed	Main River	Tributaries	Migration Distance	Survey Date	Abundance
Nisqually River	Nisqually River		35.0	7/8/1930	B
		Mashel River	10.0	6/30/1930	B
		Beaver Cr.	NA	6/28/1930	D
		Big Cr.	NA	7/12/1930	X
		Busy Wild Cr.	NA	6/30/1930	D
		Catt Cr.	NA	7/6/1930	X
		Lynch Cr.	1.0	6/26/1930	D
		O'Hop Cr.	6.0	6/26/1930	D
		Mineral Cr.	NA	7/10/1930	X
		Muck Cr.	16.0	6/24/1930	C
		Little Nisqually River	NA	7/3/1930	X
		Yelm Cr.	1.0	4/3/1930	C
		L. Mashel River	0.3	7/4/1930	D
Deschutes River	Deschutes River		NA	6/27/1930	X

Appendix B. Hatchery population evaluation procedure (from Good et al. 2005)

In the SSHAG document, each hatchery stock was assigned to a category based on variation across three axes (Table B-1): 1) the degree of genetic divergence between the hatchery stock and the natural populations that occupy the watershed into which the hatchery stock is released, 2) the origin of the hatchery stock, and 3) the status of the natural populations in the watershed. There are four categories of divergence: minimal, moderate, substantial, and extreme. Minimal divergence means that, based on the best information available, there is no appreciable genetic divergence between the hatchery stock and the natural populations in the watershed (e.g., because the hatchery and wild populations are well mixed in each generation). Moderate divergence means the level of divergence between the hatchery stocks and the local natural populations is no more than what would be expected between closely related populations within the ESU. Substantial divergence is roughly the level of divergence expected between more distantly related populations within the ESU. Extreme divergence is divergence greater than what would be expected among natural populations in the ESU, such as that caused by deliberate artificial selection or inbreeding. The second axis describes the origin of the hatchery stock, and it can either be local, nonlocal but predominantly from within the ESU, or predominantly from outside of the ESU. The third axis describes the status of the natural populations in the watershed of the same species as the hatchery stock, which can either be native or nonnative.

Category 1 stocks are characterized by no more than minimal divergence between the hatchery stock and the local natural populations and regular, substantial incorporation of natural origin fish into the hatchery broodstock. Within category 1, category 1a stocks are characterized by the existence of a native natural population of the same species in the watershed, and category1b stocks are characterized by the lack of such a population (i.e., the local, naturally spawning population was introduced from elsewhere). Note that a category 1a designation can describe a range of biological scenarios, and does not necessarily imply that the hatchery stock and the associated natural population are close to a "pristine" state. For example, a hatchery program that started many years ago with local broodstock and regularly incorporated local natural-origin fish in substantial proportions thereafter would likely be a Category 1a, even if both the hatchery stock and the local natural population have diverged from what the natural population was like historically.

Category 2 stocks are no more than moderately diverged from the local, natural populations in the watershed. Category 2a stocks were founded from a local, native population in the watershed in which they are released. Category 2b stocks were founded nonlocally, but from within the ESU, and are released in a watershed that does not contain a native natural population. Category 2c stocks were founded nonlocally, but from within the ESU, and are released in a watershed that contains a native natural population.

Category 3 stocks are substantially diverged from the natural populations in the watershed in which they are released. The a, b, and c designations are the same as described for Category 2 above.

Category 4 stocks are characterized either by being founded predominantly from sources that are not considered part of the ESU in question, or by extreme divergence from the natural populations in the watershed in which they are released, regardless of founding source.

Table B-1. Summary of the hatchery program categorization system.

	Local; native natural population	Non-local but within ESU; no native local natural population	Non-local but within ESU; native local natural population exists	Non-local and predominantly from outside of ESU
Substantial natural origin fish in broodstock and minimal divergence	1a	1b	NA	4
Moderate to few natural-origin fish in broodstock and no more than moderate divergence[a]	2a	2b	2c	4
Substantial divergence[b]	3a	3b	3c	4
Extreme divergence[c]	4	4	4	4

[a] Moderate divergence = no more than observed between similar populations within ESU.
[b] Substantial divergence = comparable to divergence observed within entire ESU.
[c] Extreme divergence = greater than divergence observed within ESU or substantial artificial selection or manipulation.

Appendix C. Puget Sound Steelhead Hatchery Broodstock Review[1]

The conclusions of the SSHAG members were highly consistent across all of the hatchery programs being reviewed. SSHAG members were unanimous in allocating the majority of allocation votes to a specific category for all of the programs, except for the Lake Washington, Green River natural, Hamma Hamma, and Elwha River winter-run steelhead programs.

Table C-1. Distribution of hatchery allocation votes by the Salmon Steelhead Hatchery Assessment Group (SSHAG) for steelhead hatchery programs releasing fish in Puget Sound. Shaded cells indicate the overall average category (rounded to the nearest whole number). SSH, summer-run steelhead; WSH, winter-run steelhead.

	Hatchery Category				
Hatchery Stock	1.00	2.00	3.00	4.00	Average
Chambers Creek WSH	0.00	0.33	9.67	0.00	2.97
Skamania Hatchery SSH	0.00	0.00	0.00	10.00	4.00
Regional Egg Pool WSH	0.00	0.17	9.83	0.00	2.98
Bogachiel Hatchery WSH	0.00	0.33	8.17	1.50	3.12
Nooksack River Hatchery WSH	0.00	0.50	9.50	0.00	2.95
Whatcom Creek Hatchery WSH	0.00	1.00	9.00	0.00	2.90
Samish River Hatchery WSH	0.00	0.00	10.00	0.00	3.00
Skagit River Hatchery WSH	0.00	1.00	9.00	0.00	2.90
Stillaguamish Hatchery WSH	0.00	1.00	9.00	0.00	2.90
North Fork Stillaguamish SSH	0.00	0.00	1.00	9.00	3.90
South Fork Stillaguamish SSH	0.00	0.00	1.00	9.00	3.90
Snohomish River Hatchery WSH	0.00	1.00	9.00	0.00	2.90
Snohomish River Hatchery SSH	0.00	0.00	1.83	8.17	3.82
Lake Washington WSH	5.67	3.83	0.50	0.00	1.48
Green River Natural WSH	3.83	3.67	2.50	0.00	1.87
Green River Hatchery WSH	0.00	0.67	9.33	0.00	2.93
Green River Hatchery SSH	0.00	0.00	1.83	8.17	3.82
Puyallup River Hatchery WSH	0.00	0.67	9.33	0.00	2.93
White River Hatchery WSH	0.00	0.67	9.33	0.00	2.93
Deschutes River Hatchery WSH	0.00	0.50	9.33	0.17	2.97
Hamma Hamma River WSH	6.33	2.17	1.50	0.00	1.52
Hood Canal Hatchery WSH	0.00	0.50	9.33	0.17	2.97
Dungeness Hatchery WSH	0.00	0.50	8.33	1.17	3.07
Morse Creek Hatchery WSH	0.00	1.00	8.83	0.17	2.92
Elwha Hatchery WSH	0.50	2.17	5.17	2.17	2.90

[1] The Puget Sound Salmon Steelhead Hatchery Assessment Group (SSHAG) consisted of Jonathan Drake, Dr. Michael Ford, Dr. Richard Gustafson, Dr. Jeffrey Hard, Dr. James Myers, Tim Tynan, and F. William Waknitz.

Stock name: Chambers Creek Winter-run Steelhead
Broodstock Origin and History: The Chambers Creek winter-run steelhead (CCWS) stock was founded in the 1920s from the collection and spawning of native adult fish trapped in Chambers Creek, a south Puget Sound tributary. The propagation of Chambers Creek steelhead at this location occurred through 1945, when a new steelhead rearing program was initiated, leading to marked changes in this stock. In this new program, adult steelhead captured in Chambers Creek were transferred to the South Tacoma Hatchery in the upper watershed, where relatively warm water (12º C) was available to accelerate spawning maturation time. Additionally, the earliest maturing fish were selected for propagation. Continuous year-to-year use of these practices, combined with the warmer water and nutritional advances provided by newly developed dry diets allowed the production of smolts in one year instead of two. The first hatcheries outside the Chambers Creek watershed to use this stock were located on the Green and Puyallup rivers and Tokul Creek. The progeny of adult returns established through CCWS transplants to these and other Puget Sound hatchery release sites were transferred back to Chambers Creek when needed to off-set egg take short-falls, and were incorporated back into the winter-run steelhead population maintained at the site (Crawford 1979). However, as a standard practice, Chambers Creek was maintained as the lone annual source of eggs for other hatcheries.

Chambers Creek Hatchery, originally a private trout hatchery, was purchased by the Washington Department of Game in 1972 and rebuilt. This hatchery was subsequently used to propagate and further develop the Chambers Creek winter-run steelhead stock and became the major source of winter-run steelhead broodstock for western Washington. Chambers Creek –derived winter-run steelhead have been propagated and released from most Puget Sound steelhead facilities, including; Reiter Ponds, Tokul Creek, Wallace River, Dungeness, Bogachiel, Hurd Creek, Eells Springs, Kendall Creek, McKinnon Ponds, Samish, Lake Whatcom, Puyallup, Soos Creek, Voights, Creek, Marblemount, Barnaby Slough, Grandy Creek, Fabors Ferry, Baker River, Davis Slough, Whitehorse Ponds, Arlington, and the Chambers Creek facilities. Most of the programs using this transplanted stock are still active. Due to an outbreak of IHN, no winter-run steelhead have been transferred out of or propagated at the Chambers Creek facility since 1984.
Year founded: Current Chambers Creek winter-run steelhead lineage began in 1945
Broodstock size and natural population size: N/A
Subsequent events after founding: Early adult return and maturation timing were continually selected for to produce a one-year-old smolt and to provide an early returning adult that could be harvested in November through January instead of February through June. An artifact of this program was that the early spawning time of the CCWS stock reduced the likelihood of spawning with native stock. In most years prior to the mid-1980s, CCWS adult returns established at other Puget Sound hatchery release sites were not collected for use as broodstock or to create a localized return based on the transplanted stock. Eggs collected from broodstock returning to hatcheries other than Chambers Creek were sometimes used to augment egg take and/or smolt production deficiencies at Chambers Creek Hatchery. These eggs were mixed at a central hatchery (through an approach known as the "Regional Egg Pool Program") and distributed to

meet smolt production quotas at the various release sites within the Puget Sound region. This centralized egg production approach was revised beginning in the 1990s due to genetic considerations, fish disease control requirements, and chronically declining adult return levels at Chambers Creek. Transplanted CCWS stock adult returns established at most rearing locations in the region are now collected at each specific release site as broodstock to meet on-station egg and smolt production objectives (Crawford 1979, Busby et al. 1996).

Recent events since 1990: In 1993, protocols at hatcheries using Chambers Creek derived stock were modified so that eggs and fry were returned to their hatchery of origin, if possible. The modified protocols still allowed for transplantation of Chambers Creek derivative stock from another location to offset any egg-take shortfalls at a particular release location.

Relationship to current natural population (interaction between hatchery and wild fish): The original goal of the Chambers Creek program was to produce an early returning adult steelhead that smolted after one year. By the mid 1970s, it was realized that the advanced adult spawn timing selected to meet the yearling smolt objective created temporal separation in natural spawning areas between CCWS and native late-winter-spawning steelhead, reducing the likelihood of interbreeding (Crawford 1979, Busby 1996).

Program goal or use of broodstock: The Chambers Creek Hatchery program was designed to collect all returning adults to Chambers Creek in order to fill regional production needs. The hatchery is no longer used to collect or propagate this winter-run steelhead stock.

Genetic Data: The original Chambers Creek winter-run steelhead stock was collected from native returns to Chambers Creek, with the likelihood of significant genetics changes due to selection for early maturation. Smolts originating from adults returning to the Green (Soos Creek), Nemah, and Samish rivers have apparently been released into Chambers Creek, so this stock presumably has a rather complicated gene background. The mixture has proven adaptable to Puget Sound streams. By 1979, as much as 90% of the total catch in some streams was attributable to plants of Chambers Creek stock. Effective population size is not known due to pooling of gametes during spawning at Chambers Creek. Historical genetic data for the original Chambers Creek stock allowing for quantification of this divergence are lacking, but differences imposed in run, spawn, and smolt emigration timing for the Chambers stock would support the hypothesis that there have been attendant, major genetic diversity changes in the population.

Phenotypic Data: Winter-run steelhead returned to Chambers Creek Hatchery from mid-December to February. The original winter-run steelhead population in Chambers Creek has been subjected to purposeful selection for over six decades, and is very likely more than moderately diverged from the donor native population.

Category and Rationale: Although the Chambers Creek Hatchery winter-run steelhead broodstock was initially established using local origin adults, SSHAG considered the intentional and unintentional selection of life history traits as a major factor in their evaluation. The advancement in run and spawn timing of the Chambers Creek winter-run steelhead (almost two months) has dramatically altered the reproductive connectivity between the hatchery-origin and naturally-spawning adults. Additionally, the sole use of hatchery-origin fish for hatchery broodstocks greater increases the potential for hatchery domestication. Comments provided by WDFW suggest that Chambers Creek winter-run steelhead have a poor rate of natural spawning success. Members allocated the 96% of their votes for Chambers Creek winter-run steelhead to Category 3.

Chambers Creek Derivatives

The majority of winter-run steelhead hatchery broodstocks in Puget Sound are derived from the Chambers Creek population. In general, there has been an active exchange of broodstock among hatcheries. Recently, mass marking has assured that hatcheries only utilize hatchery propagated fish in their broodstocks. Prior to marking, run and spawn timing was used to identify hatchery-origin fish. Given the exchange between hatcheries and efforts to exclude local naturally-produced fish it is unlikely that there has been much local adaptation by the hatchery broodstocks. For convenience, we have listed the hatchery broodstocks derived from Chambers Creek below, with special notation of conditions that might influence the hatchery category score.

Stock name: Regional Egg Pool
Broodstock Origin and History: The Regional Egg Pool stock is a CCWS-derivative population maintained at South Tacoma Hatchery. This stock was established using the warmer water available at the hatchery to accelerate spawning time and encourage CCWS to smolt at one year of age rather than two, thereby significantly reducing the cost for rearing this species in fresh water. Rearing in warmer water also helped provide uniform size smolts for distribution to Puget Sound Rivers.
Year founded: 1960s
Broodstock size and natural population size: Initially broodstock were collected at the mouth of Chambers Creek. However, over the years, eggs collected at several locations were reared at the South Tacoma Hatchery for the Regional Egg Pool, including eggs transferred from the Skykomish, Skagit, Stillaguamish, and Bogachiel rivers, and Tokul Creek.
Subsequent events after founding: By the 1970s it became evident that the early run timing that allowed the production of smolts in one year could also be used to help segregate naturally-spawning hatchery steelhead from native stocks in most streams tributary to Puget Sound, thereby decreasing the opportunity for hybridization.
Recent events since 1990
Relationship to current natural population (mixing between hatchery and wild:
Program goal or use of broodstock: Incubate and rear Puget Sound winter-run steelhead for transfer to other hatcheries to augment deficiencies in smolt production.
Genetic Data: The original Chambers Creek winter-run steelhead stock was founded using native adult returns. The stock later became an admixture of Chambers Creek-derivative stocks, through incorporation of eggs transferred back into the program from other Puget Sound watersheds location where the stock had become established through repeated hatchery releases. The mixing of eggs, combined with selective practices applied at the hatchery, likely led to significant genetics changes.
Phenotypic Data:
Category and Rationale:

Stock name: Bogachiel Hatchery Winter-run Steelhead
Broodstock Origin and History: This stock is derived from Chambers Creek Hatchery stock, with an unknown, but likely small contribution from Bogachiel River (Olympic Peninsula Steelhead ESU 2) native winter-run steelhead. The Bogachiel Hatchery program began producing steelhead in 1967 with a combination of native Bogachiel River winter-run fish and Chambers Creek fish. Chambers Creek-derivative winter-run steelhead were transferred from several hatchery locations to stock the newly constructed Bogachiel Pond in the mid-1970s. A trap was operated at the base of the pond outlet to collect early returning adults that recruited as volunteers. Since the initial transfer and establishment of the Chambers Creek-derivative stock at the ponds, the source of broodstock used to sustain the Bogachiel Hatchery winter-run steelhead program have been these early-returning adult fish volunteering to the hatchery trap. Two acclimation ponds were constructed on the Calawah River in 1976, and adult returns to the site were initiated using Chambers Creek stock. However, fish for release at the Calawah River site are currently obtained as progeny of Bogachiel Hatchery returns (Crawford 1979, HSRG 2004)
Year founded: Bogachiel Hatchery was founded in 1967, the Bogachiel Pond became operative in the mid-1970s, and the Calawah Ponds began production in 1976.
Broodstock size and natural population size:
Subsequent events after founding: In the Puget Sound ESU, Bogachiel Hatchery-origin winter-run steelhead have been transferred into the Nooksack, Samish, Skagit, Stillaguamish, Skykomish, Snoqualmie, Green, Puyallup, Deschutes, Union, Tahuya, Dewatto, Skokomish, Duckabush, Dosewallips, Quilcene, Dungeness, and Elwha rivers, and Whatcom, Kennedy, Goldsboro, and Morse creeks.
Recent events since 1990
Relationship to current natural population (mixing between hatchery and wild: Only returning adults marked with an adipose clip are spawned; wild fish are returned to the river. Surplus returning hatchery fish are directly harvested (distributed or disposed of) and not returned to the river.
Program goal or use of broodstock: The Bogachiel Pond is designed to rear 200,000 winter-run steelhead smolts, and the two Calawah Ponds 220,000 smolts. These ponds were built to increase production of winter- and summer-run steelhead in the Quillayute River systems and to provide winter-run steelhead eggs for other programs.
Genetic Data: This is considered to be a locally adapted, non-native stock. Genetic samples taken in 1993 show the Bogachiel stock to be very similar to the CCWS hatchery stock (Phelps et al. 1997).
Phenotypic Data: Winter-run steelhead return to these hatcheries from late November through February.
Category and Rationale: Largely due to the Chambers Creek hatchery broodstock influence over 80% of the allocation votes were for Category 3. The possibility of local Bogachiel River winter-run steelhead being included in the broodstock, resulted in a 15% allocation of votes into Category 4.

Stock name: Nooksack River Hatchery Winter-run Steelhead –WDFW

Broodstock Origin and History: This program was started with transfers from Tokul Creek Hatchery, and augmented with eggs from Barnaby Slough, Marblemount Hatchery, and Bogachiel Hatchery (all Chambers Creek winter-run steelhead derivatives**).**
Year founded: The Kendall Creek Hatchery winter-run steelhead program began in 1991, and the satellite program at McKinnon Ponds began in 1988. Hatchery winter-run steelhead have been released here since at least 1950. Small numbers of summer-run steelhead were released between 1972 and 1981 (HSRG 2003).
Broodstock size and natural population size: 86 to 100 fish are needed for broodstock. In 2000, only 18 were trapped (8 females).
Subsequent events after founding: It has been generally not possible to meet program needs without transferring eggs from the Skagit, Tokul Creek, or Bogachiel hatcheries.
Recent events since 1990: 2001 was the first year all of the eggs for the program were taken at Kendall Creek Hatchery.
Relationship to current natural population (mixing between hatchery and wild: All releases are marked. Early spawn timing apparently minimizes inbreeding with wild stocks. Only marked fish are used as broodstock.
Program goal or use of broodstock: The program goal is to produce fish for recreational and tribal harvest. 10,000 smolts are released on station, and 50,000 are transferred to McKinnon Pond (first release in 1988) for release into the Middle Fork Nooksack River after several months of imprinting. The goal is to spawn all fish from early December through January and only spawn in February when the run size is small.
Genetic Data: Genetic studies indicate little gene flow between CCWS and naturally spawning populations, due to difference in spawn timing.
Phenotypic Data:
Category and Rationale: This program, founded with Chambers Creek origin broodstock, continues to be operated in a manor to isolate it from native naturally-spawning winter-run steelhead in the Nooksack River. SSHAG members allocated over 90% of their votes to Category 3.

Stock name: Whatcom Creek Hatchery Winter-run Steelhead – Bellingham Technical College and WDFW.
Broodstock Origin and History: This program began with transplants from Tokul Creek, Barnaby Slough, Marblemount, and Bogachiel hatcheries (HSRG 2003).
Year founded: 1979
Broodstock size and natural population size: Fish are imported annually from Kendall Creek for release. Any wild (unmarked) fish are passed upstream. Only marked fish are used as broodstock. Prior to the initiation of the hatchery program, it is not clear if steelhead were present in Whatcom Creek. WDFW's HGMP for the program states that there were no natural steelhead in Whatcom Creek prior to releases by the hatchery.
Subsequent events after founding: This program has been augmented with eggs from the Barnaby Slough, Marblemount, Bogachiel, and Kendall Creek hatcheries. The program is currently maintained by transplants from Kendall Creek, with eggs received from Marblemount or Tokul Creek when necessary.

Recent events since 1990: Recently, returns to Whatcom Creek are augmented with transfers from Kendall Creek, which in turn is augmented with transfers from Marblemount and Tokul Creek hatcheries
Relationship to current natural population (mixing between hatchery and wild: All releases are marked. Run timing of hatchery fish and wild fish seem to be similar, suggesting that wild fish represent naturally spawning descendents of hatchery releases. In 1979, 14.3% of natural spawners were hatchery fish, in 1980, 9.5% were hatchery fish, and in 1981, 26.8% were hatchery fish.
Program goal or use of broodstock: 5,000 yearling smolts are released at Bellingham Technical College after early rearing at Kendall Creek. Winter-run steelhead are also reared here for release into the Samish River (35,000 yearlings per year).
Genetic Data: N/A
Phenotypic Data:
Category and Rationale: The relatively continuous release of Chambers Creek origin winter-run steelhead over the last several ears, in addition to the small size of the natural origin run was influential in the allocation of over 90% of the votes to Category 3.

Stock name: Samish River Hatchery Winter-run Steelhead – Bellingham Technical College and WDFW
Broodstock Origin and History: Stock was originally imported from the South Tacoma Hatchery (CCWS). Significant subsequent transfers into the Samish Hatchery have come from the Skagit, Tokul Creek, and Bogachiel Hatcheries (all CCWS derivatives) (HSRG 2003).
Year founded: Hatchery winter-run steelhead have been released here since at least 1950.
Broodstock size and natural population size:
Subsequent events after founding:
Recent events since 1990: Direct transfers from Kendall Creek Hatchery were discontinued in 2003. Production for the program is now supplied through annual transfers from Whatcom Creek Hatchery (HSRG 2003)
Relationship to current natural population (mixing between hatchery and wild: All releases are marked. Fish are released with no acclimation period and may not have sufficient time for imprinting. Early spawn timing is thought to minimize inbreeding with wild stocks
Program goal or use of broodstock: 35,000 yearling smolts released into the Samish River each year, with incubation and early rearing at Kendall Creek Hatchery and seven months of rearing at Whatcom Creek Hatchery.
Genetic Data:
Phenotypic Data:
Category and Rationale: The continued predominance of Chambers Creek Hatchery origin winter-run steelhead in this hatchery was the major factor in placing all of the allocation votes in Category 3.

Stock name: Skagit River Hatchery Winter-run Steelhead - WDFW
Broodstock Origin and History: Originally, this stock was maintained through transplants from the South Tacoma Hatchery (CCWS), with final rearing at Barnaby Slough Ponds before release into the Skagit River. All fish presently used for broodstock are marked, hatchery-origin fish returning to the Skagit River basin release sites (HSRG 2003).
Year founded: Hatchery winter-run steelhead have been released here since 1950. Summer-run steelhead were planted in the Skagit River system from 1970 to 1998.
Broodstock size and natural population size:
Subsequent events after founding: Until 1995, this stock was a mixture of fish from the Regional Egg Pool/Chambers Creek Hatchery and returns to the Skagit River, except in those years when adult returns were sufficient to meet egg production goals.
Recent events since 1990: Program is now maintained by adult returns to Marblemount Hatchery and Barnaby Slough Ponds, and marked fish at the Baker River trap. A total of 535,000 smolts are released each year from facilities at Marblemount, Barnaby Slough, Grandy Creek, Fabors Ferry, Baker River, and Davis Slough.
Relationship to current natural population (mixing between hatchery and wild: Released fish are all adipose fin clipped with no CWT. Hatchery fish comprise a portion of the natural spawning population, but no introgression has been documented. Spawn timing differences are thought to minimize wild/hatchery interactions. The hatchery stock is of locally adapted Chambers Creek origin and is segregated from the wild population genetically and temporally (WDFW HGMP, 2003). Surplus hatchery fish are returned to the lower river to provide harvest opportunities.
Program goal or use of broodstock: Goal is to provide 5,000 adults for recreational and tribal harvest, and to return 400 adults to both the Marblemount Hatchery and Barnaby Slough, as well as to supply eggs to other regional programs. Adults are trapped Dec. 1 to Feb 28, with peak spawning in mid-January. Only clipped fish used for broodstock. Between 1995 and 2001, an average of 99 females (range = 17 to 277) returned to Marblemount, with an average of 100 females (range = 15 to 227) returning to Barnaby Slough
Genetic Data: Although samples were not available from the Skagit River hatchery program, the Skagit River naturally-produced populations are distinct from other Chambers Creek derived hatchery broodstock (Phelps et al. 1997). In fact, the Skagit River and Chambers Creek are located in different Genetic Diversity Units (GDUs) established by WDFW (Phelps et al. 1997).
Phenotypic Data:
Category and Rationale: Hatchery broodstock collection protocol encourage the isolation of this Chambers Creeks-origin program. Continued isolation in this and other programs could increase the rate of domestication. 90% of the allocation votes were for Category 3.

Stock name: Stillaguamish Hatchery Winter-run Steelhead–WDFW and Stillaguamish Tribe

Broodstock Origin and History: Derived from transfers from the South Tacoma Hatchery (CCWS). CCWS have been planted in the Stillaguamish River system for more than 50 years (HSRG 2002).
Year founded: Whitehorse Ponds were built in 1955, and the Arlington Hatchery was built in 1939. Hatchery winter-run steelhead have been released here since at least 1950.
Broodstock size and natural population size: The broodstock goal is about 75-100 females. Since 1994, an average of 80 females have returned to the Whitehorse trap.
Subsequent events after founding: Since the 1980s, this stock has been maintained by returnees to Whitehorse Ponds on the North Fork of the Stillaguamish River and supplemented by eggs from Tokul Creek or Reiter Ponds winter-run steelhead.
Recent events since 1990: All eggs are collected and eyed at Whitehorse Ponds, but incubation and juvenile rearing is undertaken at the Arlington Hatchery (Whitehorse release) and Harvey Creek Hatchery. Up to 25,000 Snohomish River winter-run steelhead from Reiter Pond are planted annually in Pilchuck and Canyon creeks, with an additional 15,000 released from the Masonic Park acclimation pond into the South Fork Stillaguamish River. Prior to 1993, eggs collected in the Stillaguamish system were placed into the Regional Egg Pool. Since 1993, priority has been given to on-station release of progeny of adults that returned to Whitehorse Ponds (HSRG 2002).
Relationship to current natural population (mixing between hatchery and wild: Winter-run steelhead return to Whitehorse Pond from late November through February, with peak spawning in mid January. Surplus hatchery broodstock are held in the hatchery until they spawn, and are then released back into the river.
Program goal or use of broodstock: This program requires inter-facility transfers of eggs and fish to meet the goal of producing winter-run steelhead for Stillaguamish and Skykomish river tribal and recreational fisheries. 100,000 winter-run steelhead are targeted for release into the North Fork of the Stillaguamish River, and 80,000 for other locations. Acceptable stocks are CCWS-derived Stillaguamish winter-run steelhead or any CCWS derivative
Genetic Data: Genetic studies have shown limited amounts of hatchery introgression into the natural populations in the watershed associated with use of this stock (Phelps et al. 2003).
Phenotypic Data: The hatchery population originated from Chambers Creek Hatchery returns and is distinct in their return timing of December-early February versus the February-early May for the wild winter-run steelhead population (HSRG 2003).
Category and Rationale: This broodstock has been substantially influenced by transfers of Chamber Creek origin winter-run steelhead. The SSHAG allocated 90% of its votes to Category 3, with the remaining 10% allocated to Category 2. Some members suggested that there was a small probability that local winter-run steelhead had been included in the hatchery broodstock, or that there was some natural reproduction by hatchery-origin fish.

Stock name: Snohomish River Hatchery Winter-run Steelhead - WDFW
Broodstock Origin and History: Derived from Tokul Creek Hatchery (CCWS derivative from the Snoqualmie River Basin) and Reiter Ponds (Skykomish River Basin). CCWS have been planted in the Snohomish River system for over 50 years.

Year founded: The current Tokul Creek hatchery program started in the early 1960s with CCWS returns collected at the station. Initial winter-run steelhead releases were made at the site in the 1930s. Reiter Ponds were built in 1974 and an incubation building was built in 1988. Hatchery winter-run steelhead have been released here since 1950.
Broodstock size and natural population: Broodstock needs for both winter-run steelhead programs in the watershed are met through collection of 900 adult fish (goal level) at the Tokul Creek Hatchery weir. Since 1993, an annual average of 317 females have been spawned from fish trapped at the weir, located in Tokul Creek, a right bank tributary to the Snoqualmie River near the base of Snoqualmie Falls. After annual production needs for the Tokul and Reiter Pond programs are met, surplus eyed eggs are transferred to other hatcheries throughout Puget Sound. Excess hatchery fish are returned to the river to provide harvest opportunities (HSRG 2002).
Subsequent events after founding: This stock has been propagated from adults returning to Tokul Creek Hatchery and (if needed) from Whitehorse Ponds (Stillaguamish River) since the late 1970s. Tokul Creek Hatchery was a primary contributor to the Regional Egg Pool of winter-run steelhead eggs for Puget Sound hatcheries.
Recent events since 1990: In the mid 1990s full-term rearing was initiated at Tokul Creek Hatchery.
Relationship to current natural population (mixing between hatchery and wild: This hatchery stock returns from late November through February, with peak spawning in February. Surplus adults are returned to the river at Tokul Creek and Reiter Ponds to provide additional harvest opportunity for sports anglers.
Program goal or use of broodstock: 270,000 yearlings are released into the Skykomish River at various points each year. Eggs are collected primarily from adults returning to the Tokul Creek Hatchery from November 20th to February 10th. The Wallace River Hatchery provides intermediate and final rearing for the fish released into the Wallace River, and intermediate rearing for the group released from Reiter Ponds. 185,000 yearlings are released each year into the Snoqualmie River basin, primarily from the Tokul Creek facility. 15,000 yearlings from the Whitehorse Ponds are released into the Pilchuck River. Acceptable stocks include CCWS-derived Skykomish winter-run steelhead, or any CCWS derivative. This program is a source for inter-facility transfers of eggs and fish.
Genetic Data: Analysis by Phelps et al. (1997) suggests little introgression by Chambers Creek derived broodstock.
Phenotypic Data:
Category and Rationale: The category allocation for this hatchery broodstock was similar to other Chambers Creek derived populations: 90% in Category 3 and 10% in Category 2. This reflects the view that the Snohomish River winter-run steelhead are substantially diverged from the Chambers Creek winter-run steelhead.

Stock name: Green River Hatchery Winter-run Steelhead – WDFW and Muckleshoot Tribe.
Broodstock Origin and History: This program was started with introductions from CCWS and is currently maintained by adult returns to Palmer Ponds, with

supplementation from Tokul Creek or Bogachiel hatcheries when needed. In the last few years, more than 50% of the eggs for this program have come from Tokul Creek Hatchery (HSRG 2003).
Year founded: Hatchery winter-run steelhead have been released into the Green River watershed through this program since at least 1950. The current program was initiated in 1969
Broodstock size and natural population size: Broodstock goal is 200 adult steelhead, 100 females and 100 males.
Subsequent events after founding: At Palmer Ponds, winter- and summer-run steelhead juveniles are merged into one pond prior to release. At Soos Creek Hatchery, juvenile winter- and summer-run steelhead are reared separately. At Palmer Ponds, adult winter- and summer-run steelhead are held in separate ponds. At Soos Creek Hatchery, adult winter- and summer-run steelhead are held in the same area.
Recent events since 1990: From 1997 to 2001, 5, 6, 56 (from Tokul Creek), 7, and 6 females returned to Palmer Ponds and were used as broodstock. Between 1992 and 2001, SAR averaged 1.09%, with a range of 0.28% to 2.44%. The program SAR goal is 5% (HSRG 2003).
Relationship to current natural population (mixing between hatchery and wild: Fish return from late November through February, with peak spawning in mid January. Early spawn timing minimizes inbreeding with native stocks. Only marked, hatchery-origin, fish are used for broodstock. Approximately 8% of the returning adults from this program spawn naturally, mostly prior to mid March. All releases are adipose clipped.
Program goal or use of broodstock: Program goal is to augment recreational and tribal harvest. The goal is to release 80,000 yearlings from Palmer Ponds, 35,000 yearlings from Soos Creek Hatchery, and 10,000 from Flaming Geyser Ponds to provide CCWS for tribal and recreational harvest. Acceptable alternative stocks are Tokul Creek winter-run steelhead or any CCWS derivative. Green River Hatchery winter-run steelhead have no known unique attributes.
Genetic Data: Green River naturally-spawning winter-run steelhead are genetically distinct from Chambers Creek winter-run steelhead (Phelps et al. 1997).
Phenotypic Data: Early spawn timing minimizes inbreeding with wild stocks.
Category and Rationale: Over 93% of the allocation votes were for Category 3 based, in part, on the efforts to select Chambers Creek winter-run steelhead for early run timing and hatchery protocols at the Green River Hatchery to isolate hatchery fish.

Stock name: Puyallup River Hatchery Winter-run Steelhead - WDFW
Broodstock Origin and History: The stock of steelhead used at Voights Creek Hatchery is considered Chambers Creek stock, founded with CCWS from South Tacoma Hatchery and through transfers from Tokul Creek and Bogachiel hatcheries. However, in recent years the emphasis is to utilize as many locally adapted fish as possible for the program. In years when egg take goals cannot be met with locally adapted fish, stocks from both the Bogachiel Hatchery and Tokul Creek Hatchery are used to secure an egg take. Both Bogachiel stock and Tokul Creek stock are considered Chambers Creek derivatives (HSRG 2003).
Year founded: 1947

Broodstock size and natural population size: Due to low population numbers in recent years, all returning adults are spawned. Since 1997, an average of 28 females have been collected at the Voights Creek trap. The broodstock goal for Voights Creek is 250 fish, 125 males and females.
Subsequent events after founding: This program released CCWS into the mainstem Puyallup and Carbon rivers from the 1950s until the 1990s
Recent events since 1990: Beginning in the mid 1990s, most steelhead were acclimated and released from the Voights Creek Hatchery to reduce straying and facilitate adult recovery. Since 1996, the program has been maintained by volitional returns, supplemented with fish from Bogachiel and Tokul Creek hatcheries when necessary. Fish from the 2001 brood year will be the first group that is released entirely from Voights Creek. In the late 1990s, the Puyallup Tribe maintained a separate winter-run steelhead program at Diru Creek, using CCWS. This program has been eliminated.
Relationship to current natural population (mixing between hatchery and wild: All releases are adipose fin clipped, and only adipose-fin clipped adults are collected for spawning purposes. Early spawn timing is thought to minimize inbreeding with wild stocks. Over the last 5 years, using March 15 as a separation date, hatchery fish averaged 5.8% of the natural spawners in the Puyallup River, ranging from 2.1% to 10.5%. The majority of returning hatchery-origin fish are harvested.
Program goal or use of broodstock: 200,000 yearlings are released each year from Voights Creek hatchery to augment recreational and tribal harvests. Any CCWS derivative is acceptable for release into the Puyallup River system. Between 1997 and 2000, 8, 17, 25, and 2 females returned to Voights Creek Hatchery.
Genetic Data: WDFW considers this stock is to be an introduced, non-adapted stock. Early spawn timing minimizes inbreeding with wild stocks. WDFW suggests that there are genetic differences between the hatchery broodstock and naturally-spawning "native" Puyallup River winter-run steelhead (SASI 2002, HSRG 2003).
Phenotypic Data: SARs have declined recently. From 1984 to 1988, percent survival was 4.7%; from 1989 to 1993 it was 1.0%, and from 1994 to 1999 it was 0.4%
Category and Rationale: The reliance of this program on out-of-basin Chambers Creek winter-run steelhead broodstocks suggests that there has been little local adaptation and overall fitness is low. Much of the rationale is similar to other Chambers Creek derivatives. Over 93% of the votes were allocated to Category 3.

Stock name: White River Hatchery Winter-run Steelhead - WDFW
Broodstock Origin and History: Founded with fish transferred from the Puyallup Hatchery. This program is not run independently, but is dependent on the Puyallup Hatchery Winter-run Steelhead program. The hatchery out-plant program in the White River was terminated after the springtime releases in 2002.
Year founded: Hatchery winter-run steelhead had been released here since at least 1970.
Broodstock size and natural population size:
Subsequent events after founding:
Recent events since 1990: Beginning in release year 2003, all fish originally destined for planting into the White River from the Puyallup Hatchery will be released into the Puyallup River system from Voights Creek facility.

Relationship to current natural population (mixing between hatchery and wild: All releases made into the White River prior to the program's termination were fin clipped. Early spawn timing of the hatchery stock is thought to reduce the potential for genetic interaction with naturally spawning fish. Over the last 5 years, using March 15 as a separation date, hatchery fish averaged 0.8% of the natural spawners in the White River.
Program goal or use of broodstock: Program terminated.
Genetic Data:
Phenotypic Data:
Category and Rationale: Dependence on the Puyallup Hatchery winter-run program determined SSHAG voting. Although this program has been terminated, there are still fish from the program returning to the White River.

Stock name: Deschutes River Hatchery Winter-run Steelhead - WDFW
Broodstock Origin and History: This program relies on annual outplants of CCWS from the Puyallup, Tokul Creek, and Eells Springs hatcheries.
Year founded: Hatchery winter-run steelhead have been released here since 1955. The current program was initiated in 1975.
Broodstock size and natural population size: Steelhead and other anadromous salmon are not native to the Deschutes River due to a natural migratory blockage at Tumwater Falls at the mouth, which was not laddered until 1953. No broodstock are collected from returning adults.
Subsequent events after founding: From 1975-1996, this program was maintained primarily by adult returns to the Eells Springs Hatchery (HSRG 2002).
Recent events since 1990: After 1997, this program has been maintained primarily through adult returns to the Puyallup Hatchery.
Relationship to current natural population (mixing between hatchery and wild: If a naturally spawning population is present, it represents feral CCWS.
Program goal or use of broodstock: 24,500 yearlings are released into the Deschutes River at RM 15.5 each year to provide harvest for recreational anglers. Prior to release, fish are reared at the Puyallup Hatchery. Since 1994, an average of 7 hatchery winter-run steelhead have been harvested in the Deschutes River each year.
Genetic Data: No information
Phenotypic Data:
Category and Rationale: Historically, there was no anadromous migration above Tumwater Falls on the Deschutes River. This program is primarily operated to provide harvest opportunities and it is unknown if a feral run of winter-run steelhead has been established. Regardless, SSHAG review treated this program similarly to other Chambers Creek derivatives, with over 90% of the vote allocations being put in Category 3.

Stock name: Hood Canal Hatchery Winter-run Steelhead - WDFW
Broodstock Origin and History: This hatchery stock was derived from CCWS. Initially eyed eggs from Tokul Creek Hatchery were reared to fingerling stage at the Puyallup Hatchery, and then transferred to Eells Springs Hatchery prior to release.

Currently, steelhead from the Bogachiel Hatchery are used for this program (HSRG 2004).
Year founded: Hatchery winter-run steelhead were released into the Skokomish River beginning in 1953 and the Duckabush and Dosewallips rivers beginning in 1950. Summer-run steelhead (stock unknown) were also released into the Dosewalips River between 1964 and 1981. The winter-run steelhead program was initiated in 1976. Winter-run steelhead releases from Eells Springs Hatchery into the three Hood Canal River will be terminated beginning with the 2005-06 brood year.
Broodstock size and natural population size: No adults are collected at the Hood Canal hatchery rearing and release sites.
Subsequent events after founding: The out-planting program will be terminated in 2005.
Recent events since 1990: Stocking of CCWS-derived winter-run steelhead has been terminated in all Hood Canal streams. For example, the Hamma Hamma River has not been stocked since 1954, the Big Quilcene and Dewatto rivers since 1990, and the Union and Tahuya rivers since 1994. All other out-plant program were terminated in 2005.
Relationship to current natural population (mixing between hatchery and wild: All releases were adipose clipped. Early spawn timing minimizes inbreeding with wild stocks. However, due to very low number of natural-origin returns, there is some concern about mixing between the CCWS hatchery stock and native stocks in the Dosewalips and Duckabush rivers.
Program goal or use of broodstock: SAR rates between 1988 and 2001 ranged from 0.0 to 1.23% in the Duckabush River, 0.0 to 0.33% in the Dosewallips River, and 0.03 to 2.1% in the Skokomish River. Between 1988 and 2000, sport harvest in these three streams has ranged from 0 to 115 fish in the Duckabush River, 0-118 in the Dosewalips River, and 3-100 in the Skokomish River. Over the same period, tribal harvest has ranged from 2-31 fish in the Skokomish River. There has been no tribal harvest in the Duckabush and Dosewallips rivers since 1994.
Genetic Data: Based on samples collected from the Dosewallips River, there has been little introgression by this program into the naturally-spawning population (Phelps et al. 1997).
Phenotypic Data:
Category and Rationale: Fish in this program are currently obtained from the Bogachiel Hatchery. The SSHAG scores reflected this origin, with the vast majority of votes (93%) allocated to Category 3, with the remainder in Category 2 and 4.

Stock name: Dungeness Hatchery Winter-run Steelhead - WDFW
Broodstock Origin and History: Derived from Bogachiel Hatchery (CCWS) stock.
Year founded: Hatchery winter-run steelhead have been released here since 1955. The current program was initiated in 1994.
Broodstock size and natural population size:
Subsequent events after founding: This program is maintained through the collection and spawning of fish returning to Dungeness Hatchery in addition to annual supplementation by fish or eggs from the Bogachiel Hatchery. In most years the majority of the production released from the hatchery has been from Bogachiel Hatchery transfers.

For example, in 2000, only 2 females returned to the hatchery, while in 2001, only 1 female returned (HSRG 2002).
Recent events since 1990: Program founded in 1994.
Relationship to current natural population (mixing between hatchery and wild: Considered a segregated program. The small number of fish released in combination with poor return rates poses a low risk of competition or integration with other populations.
Program goal or use of broodstock: The program is designed to provide harvest in the Dungeness River without impacting naturally spawning steelhead. The program presently relies on annual eyed egg transfers from Bogachiel Hatchery, but WDFW is attempting to establish adult returns to a level that would allow the program to be self-sustaining. From the years 1995 to 2000, 84 hatchery-origin steelhead were harvested in the Dungeness River.
Genetic Data: Phelps et al. (1997) reported that naturally-produced steelhead in the Dungeness River were distinct from winter-run steelhead from the Bogachiel Hatchery (the source for this broodstock).
Phenotypic Data:
Category and Rationale: The Bogachiel Hatchery has been a continuing sources for this program. SSHAG scores reflected the influence of these transfers, with the 83% in Category 3, 12% in Category 4, and 5% in Category 2.

Stock name: Morse Creek Hatchery Winter-run Steelhead
Broodstock Origin and History: Outplants from the Bogachiel Hatchery.
Year founded: These small streams were first planted in1962.
Broodstock size and natural population size:
Subsequent events after founding: Releases into Morse Creek were terminated beginning in 2005.
Recent events since 1990:
Relationship to current natural population (mixing between hatchery and wild: Overlap of spawn timing with wild spawners poses some risk over the long term. Busby et al. (1996) reported that half of the escapement to Morse Creek consisted of hatchery-origin adults.
Program goal or use of broodstock: Plant 25,000 smolts into the Lyre River, and 10,000 into the Pysht River.
Genetic Data: Phelps et al. (1997) reported the winter-run steelhead sampled from Morse Creek were genetically similar to Chambers Creek derived hatchery broodstocks.
Phenotypic Data:
Category and Rationale: This broodstock is largely derived from the Bogachiel Hatchery and the SSHAG determination largely reflected this, with over 88% of the allocation votes assigned to Category 3.

Stock name: Elwha Hatchery Winter-run Steelhead – Lower Elwha Klallam Tribe
Broodstock Origin and History: The steelhead program at the Lower Elwha Fish Hatchery began in 1976 utilizing a composite of available hatchery stocks, including

importations from Quinault NFH (26,297 eggs 1976-77), Eagle Creek NFH (41,277 eggs, 1976-77) and Chambers Creek (37,673 eggs 1976-77). Since the initiating year, all broodstock has originated from returning Elwha River broodstock and has included adults from both the imported (early timed) and natural-origin (late timed) populations. WDFW has had an extensive history of planting of both summer- and winter-run steelhead salmon into the river. These out-plants originated from a variety of the WDFW fish culture facilities, including Shelton, Aberdeen, South Tacoma, Bogachiel, and Calawah Ponds (HSRG 2002).
Year founded: 1958; the current program was initiated in 1976.
Broodstock size and natural population size: **The** program requires 120 adults per year for use as broodstock. The combined (hatchery and natural origin) average run size to the Elwha River is 2,229.
Subsequent events after founding: Since 1977, the program has been maintained with returns to the Lower Elwha Hatchery.
Recent events since 1990:
Relationship to current natural population (mixing between hatchery and wild): This is considered a segregated program, with early returning hatchery fish having a low probability of spawning with native late winter-run steelhead. It is unclear to what degree a native population of winter-run steelhead has persisted in the Lower Elwha subsequent to the construction of the Elwha and Glines Canyon Dams. The number of natural fish incorporated into the hatchery program annually prior to 1997 is unknown. Mass marking of all hatchery origin fish was initiated in 1997.
Program goal or use of broodstock: Goal is release 120,000 smolts annually into the Elwha River to produce adult returns for tribal and recreational harvest. The HSRG (2002) did not consider this stock as being suitable for recovery activities in the upper Elwha River.
Genetic Data: There have been identified two discrete populations of winter- run steelhead salmon on the Elwha River (USDI, 1996; Phelps et al. 1997): 1) Early component: A hatchery-derived population that forms the basis for the existing enhancement program at the Lower Elwha Fish Hatchery. Entry timing for this population begins in December and continues through February with peak spawning occurring in January; and, 2) Late component: A natural-origin population whose entry into the river begins in February and continues through June.
Phenotypic Data:
Category and Rationale: The SSHAG was somewhat more uncertain of the status of this broodstock. This was due to the incorporation of native late-winter-run steelhead into the broodstock, and the location of the Elwha River, on the western edge of the ESU (which might lead to the incorporation of out-of-ESU fish into the hatchery). The majority of SSHAG votes (52%) were allocated to Category 3, with equal weighting for Category 2 and Category 4 votes.

Puget Sound Winter-Run Steelhead – Not derived from Chambers Creek Hatchery

Stock name: Lake Washington Wild Winter-run Steelhead

Broodstock Origin and History: This program is based on the collection of naturally produced (unmarked) fish returning to the Lake Washington system were captured at the Ballard Locks for broodstock. No hatchery winter-run steelhead have been released into the Lake Washington system since 1993 (HSRG 2003).
Year founded: 1997. Hatchery winter-run steelhead have been released here between 1953 and 1993.
Broodstock size and natural population size:
Subsequent events after founding: This program is currently not operating, because broodstock collection criteria have not been met in recent years. 75 adults must return to the Ballard Locks before broodstock can be collected for the program.
Recent events since 1990: Substantial loss of returning steelhead adults at the Ballard Locks resulting from California sea lion predation has been largely addressed through harassment and deportation of individual offending animals.
Relationship to current natural population (mixing between hatchery and wild: Juvenile steelhead were planted in north Lake Washington tributaries. Released juveniles appear to be residualizing in Lake Washington. There have been no confirmed ocean returns from this program.
Program goal or use of broodstock: Eggs were incubated at the Cedar River Hatchery, and then transferred to Issaquah Hatchery for rearing prior to release. Releases of up to 20,000 yearlings from Issaquah Creek Hatchery, and 30,000 fingerlings into North Lake Washington tributaries are planned.
Genetic Data: Phelps et al. (1997) reported that Cedar River winter-run steelhead were distinct from Chambers Creek hatchery populations. Similarly, Marshall et al. (2004) found genetic differences between winter-run steelhead captured at the Ballard Locks and Chambers Creek fish.
Phenotypic Data:
Category and Rationale: Based on the natural-origin source for this broodstock the SSHAG allocation votes were primarily assigned to Category 1 (57%) and Category 2 (38%). Review of the SSHAG evaluation by the Puget Sound Steelhead BRT resulted in this program being removed from consideration. At the time of the BRT meeting (June 2005) this program was considered inactive.

Stock name: Green River Natural Winter-run Steelhead – Muckleshoot Tribe and WDFW
Broodstock Origin and History: Adults are collected by hook and line in the Green River, and matured, spawned, incubated, and hatched at WDFW's Soos Creek Hatchery. Final rearing and acclimation occurs at the Crisp Creek Rearing Ponds, a Muckleshoot tribal facility in the Green River Basin. The fish are released from the Crisp Creek facility at RM 1.1 (HSRG 2002).
Year founded: 2002
Broodstock size and natural population size: The target annual broodstock collection size is up to 50 adults. In 2002, 12 females and 30 males were collected for use as broodstock.
Subsequent events after founding:

Recent events since 1990: The program was initiated in 2002 and has been operating just three years.
Relationship to current natural population (mixing between hatchery and wild: If annual escapement objectives are met (10 to 20 females), fingerlings are adipose clipped and planted. When escapement objectives are not met, pre-smolts are unmarked and planted in areas with low natural spawning.
Program goal or use of broodstock: Plant up to 250,000 adipose clipped and ventrally marked yearlings from Crisp Creek Rearing Ponds.
Genetic Data: The program is designed to propagate and enhance the native Green River winter-run steelhead population, relying on the annual collection of naturally spawning adult fish from the mainstem river. Genetic analyses by Phelps et al. (1994) grouped Green River winter-run steelhead most closely with winter-run steelhead from the Cedar River, while also showing affinity to winter-run steelhead populations in the Snohomish and Stillaguamish watersheds.
Phenotypic Data:
Category and Rationale: Although this program is designed to collect naturally-spawning "native" winter-run steelhead, the SSHAG was somewhat more uncertain about the origin of the fish collected. Hatchery-origin winter- and summer-run steelhead are know to spawn naturally in the Green River (SASI 2002, HSRG 2003), and there is some potential for the (unmarked) progeny of hatchery-origin fish to be collected as broodstock. SSHAG allocation votes were almost equally split between Category 1 (38%) and Category 2 (37%), with the remaining 25% of the votes in Category 3.

Stock name: Hamma Hamma River Winter-run Steelhead – Long Live the Kings, Hood Canal Salmon Enhancement Group, NOAA Fisheries, Point No Point Treaty council, USFWS, WDFW
Broodstock Origin and History: Broodstock collected for this program are thought to represent indigenous winter-run steelhead. There have been very few hatchery stock transfers into the Hamma Hamma River watershed. Eyed eggs are collected from naturally spawned steelhead redds. Incubation and rearing occurs at Johns Creek Hatchery. Captive rearing of adults occurs at the Lilliwaup Hatchery (HSRG 2004).
Year founded: 1998. Hatchery (CCWS) winter-run steelhead were released here once in 1954.
Broodstock size and natural population size:
Subsequent events after founding: The planned duration of the program is up to 12 years. Recent low ocean survival trends of steelhead may hamper this program.
Recent events since 1990: In 2002, 197 captively reared 4 year-old adults were released into the Hamma Hamma River and were observed spawning.
Relationship to current natural population (mixing between hatchery and wild: Small effective size of broodstock could lead to genetic swamping effects. Due to the newness of the program, there is no information to evaluate the impact of returning hatchery-reared fish.
Program goal or use of broodstock: Release up to 5,000 two-year-old smolts and 200 captively reared adults into the Hamma Hamma River. All releases are adipose clipped.
Genetic Data:

Phenotypic Data:
Category and Rationale: In light of the short duration that this program has been in operation and the methods used for obtaining progeny, the SSHAG allocated the majority (63%) of its votes to Category 1, with remaining 22% and 15% of the votes in Categories 2 and 3, respectively. There was some uncertainty regarding the extent that captive rearing would lead to domestication effects. Similarly, some SSHAG members were unsure to what degree past hatchery introductions or current hatchery strays may have influenced this population.

Stock name: Skamania Hatchery Summer-run Steelhead
Broodstock Origin and History: This stock was founded from fish in the Washougal and Klickitat Rivers in 1963, and then transferred to many facilities for release in many ESUs, including Puget Sound, where established broodstocks are now collected (Crawford 1979, Good et al 2005). Releases occurred at the collection locations, but were also made through "off-station" transfers into other areas in the Puget Sound region. The hatchery programs in the Puget Sound steelhead ESU that currently propagate and release Skamania-origin summer-run steelhead collected from broodstock returns of the transplanted stock to the release site or from another Puget Sound location are: Whitehorse Springs Hatchery (on-station, and off-station into three other locations in the NF Stillaguamish River watershed (Canyon Creek, RM 55 and RM 60); Reiter Ponds (releases on-station, and into two other locations in the Skykomish River watershed (NF Skykomish and Sultan rivers), and one in the Snoqualmie watershed (Raging River)); and Palmer Ponds, Soos Creek Hatchery, and Keta Creek Hatchery in the Green River watershed.
Year founded: Founded in the 1963 from wild fish in the Washougal and Klickitat rivers in Washington. It is possible that wild Washougal steelhead continued to be incorporated into the broodstock after the initial founding.
Broodstock size and natural population size: N/A – This stock is no longer transferred from Skamania Hatchery for use in Puget Sound, as sufficient adult returns of this stock have been established at Reiter Ponds (and potentially Soos Creek Hatchery) for use as broodstock.
Subsequent events after founding: After the original broodstock was established at Skamania Hatchery it was transferred to other facilities in Washington and Oregon. Independent broodstocks supported by artificial propagation were subsequently established and collected at those locations. Current broodstock programs in Puget Sound streams rely on returning hatchery adults. According to SaSI (2002) native populations of summer-run steelhead are present in two Puget Sound watersheds where Skamania stock artificial propagation programs are operated (Stillaguamish basin and the NF Skykomish River).
Recent events since 1990: Transfers of this stock from its Columbia River basin-origin into Puget Sound were terminated after summer-run steelhead returns based on this stock were established at levels sufficient to sustain hatchery summer-run steelhead production in the region.
Relationship to current natural population (mixing between hatchery and wild):
The Skamania Hatchery summer-run steelhead stock is an introduced stock in all Puget

Sound streams where it is planted, including some streams that had no summer-run steelhead run prior to its introduction. Feral summer-run steelhead populations have become established in some rivers, including the Green River, the S.F. Skykomish River, and the S.F. Stillaguamish River.
Program goal or use of broodstock: This broodstock is used to provide fish for recreational harvest.
Genetic Data: Wild summer-run steelhead in all Puget Sound watersheds are genetically distinct from Skamania Hatchery summer-run steelhead (Phelps et al., 1997).
Phenotypic Data: This broodstock has undergone artificial selection for size, spawning time (advanced by over three months), and smoltification timing (one year rather than two).
Category and Rationale: Due to the out-of-ESU origin of this broodstock the SSHAG allocated 100% of its votes to Category 4.

Skamania Summer-run Steelhead Hatchery Derivatives

The use of Skamania Hatchery broodstock has been fairly widespread through Puget Sound, although in the past few years the number of programs, especially off-site releases has been reduced. The remaining hatchery programs largely, if not entirely, consist of Skamania Hatchery origin summer-run steelhead, with limited introgression into the local naturally-spawning population. We have listed these programs together (below).

Stock name: North Fork Stillaguamish River Hatchery Summer-run Steelhead - WDFW
Broodstock Origin and History: Derived from transfers of stock from the Skamania Hatchery (ESU 4 Lower Columbia River). Current source is Skamania-derived summer-run steelhead transferred from Reiter Ponds on the Skykomish River (HSRG 2002)
Year founded: 1959
Broodstock size and natural population size: No broodstock are taken at Whitehorse Ponds.
Subsequent events after founding: For the last 20 years the program has been maintained primarily from adult returns to Reiter Ponds in the Skykomish River drainage.
Recent events since 1990: Eggs are collected and eyed at Reiter Ponds and hatched and reared at the Arlington Hatchery. All releases are marked
Relationship to current natural population (mixing between hatchery and wild: Skamania stock summer-run steelhead return to Whitehorse from May through December, with peak spawning in December. First time returns to the Whitehorse trap are marked with an operculum punch and returned downstream to provide an additional opportunity for harvest. Second-time returns (those marked with an operculum punch) to the Whitehorse Ponds trap are killed and used for watershed nutrient enhancement. SaSI (2002) recognizes three naturally producing summer-run steelhead stocks in the Stillaguamish watershed. One (Deer Creek) is considered native and self-sustaining. A second population in Canyon Creek is considered of mixed, hybridized stock. The third stock in the S.F. Stillaguamish River is considered non-native, but self-sustaining. The

latter two were founded, or are currently influenced by, the Whitehorse Springs Hatchery summer-run steelhead program (HSRG 2002)
Program goal or use of broodstock: 70,000 yearlings are released from Whitehorse Ponds into the NF Stillaguamish each year. This program requires inter-facility transfers of eggs and fish Acceptable stocks are summer-run steelhead returning to the Stillaguamish and Skykomish rivers, or any other Skamania Hatchery summer-run stock derivative.
Genetic Data: WDFW considers this stock is to be an introduced, non-adapted stock. There is potential for genetic interaction with native wild summer-run steelhead in the North Fork Stillaguamish River, although genetic studies indicate that the Deer Creek (native) populations is distinct from Skamania Hatchery broostock (Phelps et al. 1997).
Phenotypic Data:
Category and Rationale: Based on the out-of-ESU source of the Skamania hatchery broodstock, SSHAG allocated 90% of its votes to Category 4. The remaining 10% were allocated to Category 3, suggesting that there may have been some introgression with local naturally-spwning fish.

Stock name: South Fork Stillaguamish River Hatchery Summer-run Steelhead.
Broodstock Origin and History: Derived from transfers of stock from the Skamania Hatchery (ESU 4 Lower Columbia River)
Year founded: 1959
Broodstock size and natural population size:
Subsequent events after founding: For the last 20 years the program has been maintained from adult returns to Reiter Ponds in the Skykomish River drainage
Recent events since 1990: Eggs are collected and eyed at Reiter Ponds hatching and early rearing is done at the Arlington Hatchery. Final rearing and release occurs at Reiter Ponds. All releases are marked
Relationship to current natural population (mixing between hatchery and wild: see North Fork Stillaguamish River
Program goal or use of broodstock: Planned annual releases include: 20-30,000 yearlings are planted in the river above Granite Falls, and 10,000 are released into Canyon Creek, a tributary to the South Fork Stillaguamish River.
Genetic Data: WDFW considers this stock is to be an introduced, non-adapted stock. There is a potential for genetic interaction with native wild summer-run steelhead in Canyon Creek. Summer-run steelhead in the South Fork Stillaguamish River are genetically similar to Lower Columbia River summer-run steelhead from the Skamania Hatchery
Phenotypic Data:
Category and Rationale: Based on the out-of-ESU source of the Skamania hatchery broodstock, SSHAG allocated 90% of its votes to Category 4. The remaining 10% were allocated to Category 3, suggesting that there may have been some introgression with local naturally-spwning fish.

Stock name: Snohomish River Hatchery Summer-run Steelhead

Broodstock Origin and History: Derived from transfers from the Skamania Hatchery (ESU 4 Lower Columbia River), Reiter Ponds stock (Skamania) summer-run steelhead, and an unknown contribution of indigenous N.F. Skykomish River basin stock. The program has been self-sustaining through adult returns to Reiter Ponds for twenty years (HSRG 2002).
Year founded: Summer-run steelhead have been planted into the Snoqualmie River since 1950, and the Skykomish River since 1959. The current program was initiated in 1974.
Broodstock size and natural population size: Average broodstock take is 600.
Subsequent events after founding: Since the 1980s this stock has been maintained by adult returning to Reiter Ponds. Eggs are incubated and reared at Wallace River Hatchery, with final release/distribution from Reiter Ponds. Throughout the 1980s, the stock was a mixture of Skamania Hatchery-derived summer-run steelhead and native fish.
Recent events since 1990: Beginning in the late 1980s, late spawning hatchery fish were not propagated in order to increase separation between wild and hatchery spawners.
Relationship to current natural population (mixing between hatchery and wild: SaSI (2002) delineates three summer-run steelhead stocks in the Snohomish watershed: Tolt River ("unknown" origin with wild production); N.F. Skykomish (largely native, with wild production); and S.F. Skykomish (non-native origin, with wild production). Summer-run steelhead have been observed in the South Fork Skykomish River since Sunset Falls was laddered in 1958. The spawn timing of the hatchery stock is believed to overlap with naturally-spawning native summer-run steelhead, but the overlap may be diminished because of current broodstock collection procedures. Wild summer-run steelhead spawn from early March through June, while hatchery summer-run steelhead spawn from late December through April. Releasing hatchery fish in the mainstem of the Skykomish and Snoqualmie rivers also reduces interactions with natural summer-run steelhead. Once annual hatchery broodstock collection goals have been met, the hatchery trap is closed and surplus adults remain in the river to provide additional harvest opportunity for sports anglers (although there is an increase in the probability of hatchery fish naturally spawning).
Program goal or use of broodstock: The goal is to release 150,000 Skamania-derived Skykomish summer-run steelhead into the Skykomish River, and 150,000 into other local rivers. Returns to Reiter Ponds have numbered 259 (1995), 252 (1996), 300 (1997), 259 (1998), 222 (1999), 175 (2000), and 227 (2001) fish. Acceptable stocks are Skamania-derived Skykomish summer-run steelhead or any other Skamania Hatchery derivative. This program is a source for inter-facility transfers of eggs and fish.
Genetic Data: WDFW considers this stock is to be an introduced, non-adapted stock. Summer-run steelhead in the South Fork Skykomish River are genetically similar to Lower Columbia River summer-run steelhead from the Skamania Hatchery (Phelps et al. 1997). WDFW is currently studying the genetic composition of fish spawning above Sunset Falls to establish the contribution of Skamania-origin fish to escapement.
Phenotypic Data:
Category and Rationale: Based on the out-of-ESU source of the Skamania hatchery broodstock, SSHAG allocated 82% of its votes to Category 4. The SSHAG scores also reflected the higher potential for native summer-run steelhead to have been incorporated into the hatchery broodstock.

Stock name: Green River Hatchery Summer-run Steelhead – WDFW and Muckleshoot Tribe
Broodstock Origin and History: Derived from transfers of stock from the Skamania Hatchery (ESU 4 Lower Columbia River) via Reiter Ponds in the Snohomish River system. This stock was largely derived from Skamania-derived hatchery stocks but some native-origin Skykomish fish have likely been included as well (HSRG 2003).
Year founded: 1969.
Broodstock size and natural population size: The program broodstock collection goals are for 80 adults (40 females and 40 males). In 1999, 2000, and 2001, 1, 4, and 25 Green River-origin females, respectively, were spawned. Summer-run steelhead were not thought to be native to the Green River prior to the introduction of Skamania Hatchery stock (SaSI 2002). There is now some limited natural production by feral summer-run steelhead. Adult production levels have averaged 947 fish over the last 12 years, ranging from 189 to 1830.
Subsequent events after founding: At Palmer Ponds, winter- and summer-run juvenile steelhead are merged into one pond prior to release. At Soos Creek Hatchery, juvenile winter- and summer-run steelhead are reared separately. At Palmer Ponds, adult winter- and summer-run steelhead are held in separate ponds. At Soos Creek Hatchery, adult winter- and summer-run steelhead are held in the same area, increasing the risk of inadvertent hybridization.
Recent events since 1990: Recently, the program has required the transfer of Skamania Hatchery-derived summer-run steelhead from the Reiter Ponds. Currently, the program is maintained by returns to Soos Creek Hatchery and Palmer Ponds, with additional transfers from Reiter Ponds as necessary (ranging from 0% to 100% over the last few years). Efforts to trap returning adults at Keta Creek and Palmer Ponds began in 2000, with the goal of developing a local summer-run steelhead broodstock from the Skamania/Skykomish stock. Adult collection occurs at Soos Creek and Keta Creek hatcheries from August 1 to November 30, and at Palmer Ponds from late September to late November (HSRG 2003).
Relationship to current natural population (mixing between hatchery and wild: All releases are adipose clipped. Fish are released in May in order to reduce the probability of residualization and to reduce co-occurrence with emigrating fall Chinook salmon juveniles in the mainstem river. An estimated 3% of the hatchery population spawns naturally in the Green River, the remainder are collected at the hatchery rack or harvested. Early spawn timing is thought to minimize interbreeding with wild stocks.
Program goal or use of broodstock: Program goal is to augment recreational and tribal harvest. Goals are to release 40,000 yearlings at Palmer Ponds, 30,000 at Soos Creek, and 10,000 from Keta Creek Hatchery Acceptable stocks are summer-run steelhead from the Skykomish River (Reiter Ponds) or any Skamania derivative.
Genetic Data: WDFW considers this stock is to be an introduced, non-adapted stock (SASI 2002). There are no know extant native summer-run steelhead in the Green River, although Skamania Hatchery fish are distinct from all native Puget Sound steelhead populations (Phelps et al. 1997).
Phenotypic Data:

Category and Rationale: Based on the out-of-ESU source of the Skamania hatchery broodstock, SSHAG allocated 82% of its votes to Category 4. The SSHAG scores also reflected the inclusion of Skykomish River fish into the broodstock.

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Appendix D. Artificial propagation of steelhead in Puget Sound

State, federal, and tribal releases of fish weighing less than 10 g are not included, except where noted (*). Data are from NMFS, WDFW, NWIFC, and USFWS. SSH, summer-run steelhead; FSH, fall-run steelhead; WSH, winter-run steelhead.

Watershed	Release Site	Race	Duration	Years	Stock	No. of fish
Nooksack	Independent Streams	WSH	1950-1993	13	Unknown	106,914
			1982-1986	5	Chambers Cr.	30,307
	Lummi Sea Ponds	WSH	1974-1986		Quinault R.	111,796
	Nooksack R.	SSH	1972-1981	4	Unknown	35,804
			1988	1	Yakima R.	52,306
		WSH	1995-2001	2	Bogachiel R.	106,477
			1982-1992	11	Chambers Cr.	788,751
			1983	1	NF Nooksack R.	15,600
			1982-2004	10	Nooksack R.	542,833
			1975-1984	4	Quinault R.	306,264
			1999-2000	2	Skagit R.	68,900
			1996	1	Stillaguamish R.	17,563
			1996-2002	4	Tokul Cr.	197,814
			1950-1994	19	Unknown	697,133
			2004	1	Van Winkle C	127,000
	Whatcom Cr.	WSH	1995	1	Bogachiel R.	5,058
			1982-1992	11	Chambers Cr.	184,593
			199-2003	3	Skagit R.	46,295
			1996-1998	3	Tokul Cr.	35,023
			1955-1994	6	Unknown	46,345
			1999	1	Whatcom Cr.	4,205
Lower Skagit - Samish	Sauk R.	SSH	1981-1993	2	Unknown	12,427
		WSH	1997-2004	2	Bogachiel R.	28,655
			1982-1992	10	Chambers Cr.	245,212
			1982-1985	4	Sauk R.	75,866
			1998-2003	4	Skagit R.	64,229
			1995-2002	7	Stillaguamish R.	151,024
			1955-1994	30	Unknown	1,231,809
	Skagit R.	SSH	1983-1992	6	Skykomish R.	151,700

Appendix D
(continued).

Watershed	Release Site	Race	Duration	Years	Stock	No. of fish
Lower Skagit - Samish	Skagit R.	SSH	1995-1998	3	Stillaguamish R.	71,256
			1971-1994	12	Unknown	1,245,943
			1988-1991	3	Washougal R.	62,851
		WSH	1996-1997	2	Baker R.	85,977
			1982-2004	3	Bogachiel R.	319,127
			1979-1998	15	Chambers Cr.	1,873,235
			1953-1962	8	Columbia R.	211,135
			1985	1	Green R.	39,647
			1988-1992	3	NF Stillaguamish R.	60,535
			1982-2004	23	Skagit R.	4,466,956
			1988-1992	5	Snohomish R.	682,980
			1999	1	Stillaguamish R.	4,380
			1997	1	Tokul Cr.	22,135
			1950-1994	34	Unknown	5,661,359
	Samish R.	SSH	1988	1	Yakima R.	40,881
		WSH	1995	1	Bogachiel R.	19,275
			1977-1991	11	Chambers Cr.	538,970
			1953	1	Columbia R.	1,850
			1985	1	Green R.	30,075
			1997-2000	4	Skagit R.	94,091
			1992	1	Snohomish R.	27,000
			1995-1996	2	Stillaguamish R.	34,658
			1996-1998	3	Tokul Cr.	27,961
			1950-1994	30	Unknown	1,365,562
			1999	1	Whatcom Cr.	2,532
Stillaguamish	Deer Cr.	SSH	1958-1981	4	Unknown	78,585
		WSH	1981	1	Unknown	10,004
	NF Stillaguamish R.	SSH	1982-1997	7	Skykomish R.	271,790
			200-2003	4	Snohomish R.	178,704
			1995-1998	4	Stillaguamish R.	159,961
			1964-1994	20	Unknown	894,962
			1987-1991	5	Washougal R.	306,472
		WSH	1997-1998	2	Bogachiel R.	111,521
			1982-1992	11	Chambers Cr.	633,227

Appendix D
(continued).

Watershed	Release Site	Race	Duration	Years	Stock	No. of fish
Stillaguamish	SF Stillaguamish R.	WSH	1999	1	Skagit R.	32,351
			1995-2003	9	Stillaguamish R.	860,686
			1950-1994	32	Unknown	1,843,221
		SSH	1984-1996	9	Skykomish R.	212,961
			2002	1	Snohomish R.	38,823
			1995-1996	2	Stillaguamish R.	26,531
			1964-1994	19	Unknown	556,133
		FSH	1995-1999	2	NF Stillaguamish R.	43,143
		WSH	1982-1997	15	Chambers Cr.	318,242
			1998	1	Skagit R.	3,960
			1996-1997	2	Skykomish R.	20,494
			1998-2002	5	Snohomish R.	52,616
			2001-2003	2	NF Stillaguamish R.	31,676
			1997	1	Tokul Cr.	4,489
			1950-1994	27	Unknown	539,749
	Stillaguamish R.	SSH	1998-2004	5	Snohomish R.	224,324
			1987	1	Washougal R.	3,525
		WSH	1982-1997	16	Chambers Cr.	369,425
			1998	2	Skagit R.	13,995
			1998	1	Snohomish R.	18,044
			1996-2004	4	NF Stillaguamish R.	174,491
			1951-1994	26	Unknown	562,380
Snohomish	NF Skykomish R.	SSH	1982-1997	12	Skykomish R.	205,879
			1998-2004	6	Snohomish R.	235,957
			1959-1994	15	Unknown	593,222
		WSH	1982-1992	11	Chambers Cr.	210,556
			1996	1	Skykomish R.	15,176
			1998-2004	5	Snohomish R.	77,772
			1950-1994	27	Unknown	592,809
	SF Skykomish R.	SSH	1982-1992	9	Skykomish R.	170,695
			2001	1	Snohomish R.	16,300
		SSH	1964-1981	8	Unknown	124,707

Appendix D
(continued).

Watershed	Release Site	Race	Duration	Years	Stock	No. of fish
Snohomish	SF Skykomish R.	WSH	2001	1	Snohomish R.	9,100
			1950-1968	4	Unknown	36,086
	Skykomish R.	SSH	1982-1997	13	Skykomish R.	1,294,502
			1998-2004	7	Snohomish R.	986,525
			1961-1994	16	Unknown	871,797
			1990	1	Wenatchee R.	14,950
			1987	1	Willamette R.	16,263
		WSH	1982	1	Bogachiel R.	32,794
			1982-1995	12	Chambers Cr.	1,800,903
			1996-1997	2	Skykomish R.	222,799
			1998-2004	7	Snohomish R.	1,343,605
			1996-1997	2	Tokul Cr.	67,603
			1950-1994	34	Unknown	2,840,449
	Snoqualmie R.	SSH	1982	1	Chambers Cr.	11,865
			1982-1997	13	Skykomish R.	649,886
			1998-2004	7	Snohomish R.	310,587
			1950-1994	20	Unknown	885,208
		WSH	1995	1	Bogachiel R.	51,748
			1982-1992	11	Chambers Cr.	
			1996	1	Skykomish R.	9,996
			1998-2004	7	Snohomish R.	1,373,651
			1995-1997	3	Tokul Cr.	344,993
			1950-1994	34	Unknown	2,757,163
Snohomish	Pilchuck R.	WSH	1997-1998	2	Bogachiel R.	15,432
			1995	1	Chambers Cr.	10,009
			1999	1	Skagit R.	5,347
			1996	1	Skykomish R.	8,606
			1999-2004	6	Snohomish R.	111,058
			1995-2004	10	Stillaguamish R.	120,983
			1997	1	Tokul Cr.	4,756
			1982	1	Bogachiel R.	17,000
			1982-1992	11	Chambers Cr.	324,805
			1985	1	Green R.	10,083
			1950-1981	28	Unknown	789,983
	Tulalip Cr.	WSH	1985-1986	2	Quinault R.	135,000

Appendix D (continued).

Watershed	Release Site	Race	Duration	Years	Stock	No. of fish
Cedar - Sammamish	Lake Washington	SSH	1966	1	Unknown	30,800
		WSH	1982-1987	3	Cedar R.	93,666
			1982-1991	9	Chambers Cr.	443,433
			1984	1	Green R.	30,798
			1982-1990	4	Lake Washington*	46,759
			1988	1	Lk Union	12,207
			1998-2002	4	Lk Wash. Native*	44,489
			1987	1	NF Stillaguamish R.	75,200
			1953-1993	25	Unknown	870,310
	N. Lk. Wash. Tribs	Native	1997-1999	3	Lk Wash. Native	39,299
Duwamish - Green	Green R.	SSH	2002-2004	3	Green R. Native	77,400
			2004	1	Snohomish R.	23,900
			1990-2004	4	Green R. Native	194,649
			1982-1999	14	Skykomish R.	950,830
			2000-2004	3	Snohomish R.	135,933
			1970-1994	14	Unknown	1,283,161
			1982	1	Washougal R.	70,238
		WSH	1999-2002	4	Grn+Tokul Wi-Sky Su	257,000
			1982-2004	6	Bogachiel R.	462,256
			1982-1997	16	Chambers Cr.	1,797,065
			1989-1991	2	Crisp Cr.	181,070
			1984-1991	5	Green R.	462,899
			1986-2004	15	Green R. Native*	1,115,389
			1990	1	Keta Cr. H.	94,844
			1992	1	NF Stillaguamish R.	11,297
			2000-2003	2	Snohomish R.	230,883
			1995-1999	4	Tokul Cr.	581,967
			1985	1	Undetermined Mixed	52,000
			1950-1994	31	Unknown	735,439
			2004	1	Van Winkle Cr.	6,885
			1985	1	White R.	5,425
Puyallup - White	Puyallup R.	SSH	1973-1980	2	Unknown	89,032
		WSH	1995-1999	3	Bogachiel R.	69,475

Appendix D
(continued).

Watershed	Release Site	Race	Duration	Years	Stock	No. of fish
Puyallup - White	Puyallup R.	WSH	1978-1994	15	Chambers Cr.	1,062,102
			1995-2000	6	Diru Cr.	340,540
			1984-1986	3	Green R.	50,062
			2004	1	Humptulips R.	216,925
			1987-1992	6	NF Stillaguamish R.	426,964
			1982-2004	11	Puyallup R.	921,225
			1981-1992	10	Quinault R.	735,806
			1999	1	Skagit R.	61,000
			1993-1998	5	Tokul Cr.	667,139
			1950-2003	38	White R.	3,868,625
	White R.	WSH	1984-2001	4	Puyallup R.	64,232
			1982-1984	3	Quinault R.	33,732
			1999	1	Skagit R.	18,210
Puyallup – White	White R.	WSH	1995-1998	4	Tokul Cr.	87,138
			1952-1994	18	Unknown	409,926
			1982-1985	4	White R.	114,225
Chambers - Clover	Chambers Cr.	WSH	1977-1996	14	Chambers Cr.	781,862
			1987-1992	6	NF Stillaguamish R.	258,750
			1950-1993	33	Unknown	1,950,900
Nisqually	Nisqually R.	SSH	1984-1985	2	Chehalis R.	36,683
			1983-1992	7	Skykomish R.	125,374
			1983	1	Soleduck R.	14,185
			1964-1994	18	Unknown	445,082
			1982	1	Washougal R.	25,403
		WSH	1958-1981	19	Unknown	387,437
Deschutes	Deschutes R.	SSH	1958-1959	2	Unknown	10,540
			1991-1992	2	Van Winkle Cr.	6,337
Deschutes	Deschutes R.	WSH	1982-2004	15	Bogachiel R.	423,430
			1997	1	Chambers Cr.	6,937
			2000	1	Puyallup R.	13,511
			1987-1991	2	Quinault R.	19,600
			1999	1	Skykomish R.	26,911
			1989	1	Tokul Cr.	34,314
			1955-1994	24	Unknown	644,098
Kennedy - Goldsborough	SSH Sound Independent	WSH	1982-1996	9	Bogachiel R.	185,068

Appendix D (continued).

Watershed	Release Site	Race	Duration	Years	Stock	No. of fish
Kennedy - Goldsborough	SSH Sound Independent	WSH	1984	1	Burley Cr.	18,070
			1984-1991	6	Quinault R.	462,764
			1989	1	Tokul Cr.	29,950
			1956-1994	16	Unknown	285,490
Kitsap	Dewatto R.	WSH	1982-1990	7	Bogachiel R.	74,002
			1987	1	Quinault R.	3,000
			1984	1	Snow Cr.	10,980
			1989	1	Tokul Cr.	14,799
			1969-1994	12	Unknown	109,763
	Grovers Cr.	WSH	1984-1988	3	Grovers Cr.	34,736
			1983-1990	8	Quinault R.	558,794
	Kitsap Independent	WSH	1957-1979	5	Unknown	62,915
Kitsap	Tahuya R.	WSH	1982-1988	6	Bogachiel R.	63,854
			19087	1	Quinault R.	10,000
			1989	1	Tokul Cr.	15,002
			1950-1994	16	Unknown	210,345
	Union R.	WSH	1982-1992	8	Bogachiel R.	84,444
			1991	1	Quinault R.	5,000
			1989	1	Tokul Cr.	14,849
			1958-1994	21	Unknown	199,420
Skokomish - Dosewallips	Skokomish R.	SSH	1972-1975	4	Unknown	82,233
			1998-1999	2	Snohomish R.	19,334
		WSH	1982-1994	14	Bogachiel R.	470,114
			1984	1	Burley Cr.	18,090
			1986	1	Elwha R.	1,680
			1987-1991	2	Quinault R.	39,959
			2000-2002	3	Snohomish R.	193,612
			1989	1	Tokul Cr.	39,975
			1953-1994	27	Unknown	609,131
	Dosewallips R.	SSH	1964-1981	7	Unknown	133,130
		WSH	1982-2003	13	Bogachiel R.	214,196
			1987-1991	2	Quinault R.	21,572
			2000-2002	2	Snohomish R.	37,593

Appendix D (continued).

Watershed	Release Site	Race	Duration	Years	Stock	No. of fish
Dosewallips	Dosewallips R.		1989	1	Tokul Cr.	25,028
			1950-1994	30	Unknown	623,158
Skokomish - Dosewallips	Duckabush R.	WSH	1982-2003	13	Bogachiel R.	196,312
			1987	1	Quinault R.	5,000
			2000-2002	3	Snohomish R.	30,211
			1989	1	Tokul Cr.	19,987
			1950-1994	29	Unknown	527,090
	Hamma Hamma R.	WSH	2002	1	Hamma Hamma Native	196- adult
			1999-20003	5	Hamma Hamma Native	7,391
			1954	1	Unknown	5,920
	Independent Streams	WSH	1990-19978	3	Bogachiel R.	52,326
			1954-1955	2	Unknown	32,156
Quilcene - Snow	Independent Streams	WSH	1979-1980	2	Unknown	730,062
			1984-1986	3	Bogachiel R.	9,179
			1991	1	NF Stillaguamish R.	953
	Quilcene R.	SSH	1951-1981	15	Unknown	178,485
		WSH	1982-1990	7	Bogachiel R.	80,960
			1987	1	Quinault R.	5,300
	Snow Cr.	WSH	1993	1	Unknown	1,274
Elwha - Dungeness	Dungeness R.	SSH	1990	1	Bogachiel R.	6,120
			1984-1986	3	Chehalis R.	20,521
			1983-1992	4	Quillayute R.	34,384
			1974-1994	10	Unknown	163,781
			1982-1987	2	Washougal R.	20,168
		WSH	1982-2001	17	Bogachiel R.	239,409
			2001-2004	4	Dungeness R.	41,931
			1991	1	Lower Elwha	30,000
			1955-1994	23	Unknown	464,208
	Elwha R.	Hybrid	1969-1971	3	Unknown	39,307

Appendix D (continued).

Watershed	Release Site	Race	Duration	Years	Stock	No. of fish
Elwha – Dungeness	Elwha R.	SSH	1990	1	Bogachiel R.	15,000
			1984-1986	3	Chehalis R.	59,981
			1983-2000	10	Quillayute R.	169,432
			1968-1993	15	Unknown	334,893
			1982-1987	2	Washougal R.	37,641
		WSH	1982-1995	7	Bogachiel R.	235,930
			1981	1	Chambers Cr.	72,608
			1978-1979	2	Eagle Cr. NFH	64,044
			1979-2004	19	Elwha R.	1,861,234
			1981-2001	12	Lower Elwha	1,600,721
			1958-1981	19	Unknown	430,280
	Morse Cr.	WSH	1982-2004	19	Bogachiel R.	192,694
			1991	1	Hoko R.	14,655
			1987	1	Quinault R.	15,227
			1962-1994	10	Unknown	108,230